MINISTRY OF
LABOUR AND NATIONAL SERVICE

Joint Standing Committee
on
Safety, Health and Welfare Conditions
in
Non-Ferrous Foundries

First Report

LONDON
HER MAJESTY'S STATIONERY OFFICE
1957

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[1] Succeeded Mr. T. W. McCullough, O.B.E., in June, 1956.
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Report on Conditions in Non-Ferrous Foundries

To Sir George P. Barnett,
Her Majesty's Chief Inspector of Factories.

Sir,

INTRODUCTION

1. In 1953 you approached the various employers' organisations and trade unions connected with the Non-ferrous Founding Industry with a view to the formation of a Joint Standing Committee to consider methods of improving the general working conditions in the Industry. This Committee, consisting of representatives of both sides of the industry together with Inspectors of Factories, was appointed with the following terms of reference.

> "To keep under review and from time to time to advise H.M. Chief Inspector of Factories on the most effective methods of implementing certain requirements of the Factories Act, 1937, and on other cognate problems in non-ferrous foundries, particularly those relating to cleanliness, lighting, ventilation and the maintenance of satisfactory atmospheric conditions, accident prevention, the provision of washing facilities and accommodation for workers' clothing, and other welfare and health services and amenities."

Mr. H. A. Hepburn, C.B.E., H.M. Deputy Chief Inspector of Factories was succeeded by Mr. T. W. McCullough, O.B.E., H.M. Deputy Chief Inspector as Chairman after the first meeting of the Committee. We have to record with great regret the death of Mr. B. Gardner, the General Secretary of the Amalgamated Engineering Union, who was a member of our Committee from its inception; and we take the opportunity of expressing our appreciation of his services.

2. When we had discussed our terms of reference, we came to the conclusion that our main considerations should be as follows:

(1) The improvement of the atmospheric environment by the suppression of dust, smoke and fumes and the control of temperature.

(2) The improvement of the appearance of foundries by cleanliness, good housekeeping, lighting and the use of colour.

(3) The provision of better amenities and more comfortable conditions in the way of messrooms, canteens, washing accommodation and so on, and

(4) the reduction of accidents.

3. It was evident from the outset that it would be no easy matter to make suitable recommendations to cover all the multifarious conditions of an industry so diverse as non-ferrous founding and our discussions have led us to the conclusion that the various metals may, even yet, have to be dealt with separately. We felt, however, that certain general matters should first be examined, and we commenced with the welfare side of the problem, because we thought that it could be dealt with generally so as to cover the whole of the industry. We decided to use the report of the Joint Advisory Committee on Conditions in Iron Foundries, referred to as the Garrett Report, as a basis for our discussions.

4. Because of the many technical matters to be considered we set up a Technical Sub-Committee with powers to co-opt. This Committee consists of Mr. A. Eyden (Chairman), Mr. J. Gardner, Mr. G. T. Hyslop, Mr. J. H. Wigglesworth and Mr. W. B. Lawrie and has engaged in limited research and development projects, in an effort to find solutions to some of the technical problems.

Our work is by no means completed, but we think that we should acquaint you of the stage which we have reached.

CLEANLINESS

5. To enable a desirable standard of cleanliness to be attained, very careful attention must be given to good housekeeping, the provision and maintenance of good floors and the suppression of dust. The old buildings in which many foundries are housed are often a handicap as they do not lend themselves readily to the maintenance of good conditions, but we are satisfied that even in these cases, the difficulties can be very largely overcome and there are instances of old foundries where the clean and orderly conditions compare most favourably with the appearance of some of the newer foundries housed in buildings of comparatively modern construction.

Section I of the Factories Act, 1937 contains a general requirement that every factory should be kept in a clean state. Additional provisions deal particularly with systematic cleaning at regular intervals, including the cleaning of floors and benches, and the treatment of internal walls and ceilings and tops of rooms. The Grinding of Metals (Miscellaneous Industries) Regulations, 1925 also contain provisions dealing with the sweeping or cleaning of rooms in which the cleaning of castings is done.

We have given careful consideration to the question of the intervals at which systematic cleaning of non-ferrous foundries should be undertaken with a view to keeping them as free as possible from the dust and dirt which inevitably accumulates there.

Whitewashing of Walls and Tops of Rooms

6. Certain non-ferrous foundries are exempted from the provisions of Section I (*c*) of the Factories Act, 1937, which, broadly speaking, require that the walls and tops of factories shall be washed, painted, whitewashed or colour-washed at least once in every 14 months. The District Inspector of Factories may however require an occupier to treat these parts as prescribed if he is satisfied that they are not in a clean state. Many foundries, which might avail themselves of this exemption, no longer do so and there appears to be no valid reason for any continuance of it. On the contrary, the periodical redecoration in light colours of the interior of a foundry would have a very valuable effect in brightening its appearance. We recommend that the exemption should be withdrawn in the case of non-ferrous foundries and that, in the meantime, full use should be made by the District Inspector of Factories of his powers to require the cleaning to be done in appropriate cases.

Removal of Dust and Dirt from Walls, Tops of Rooms and Fixtures

7. In the Grinding of Metals (Miscellaneous Industries) Regulations, it is specified that in rooms in which the cleaning of castings is done, the walls and tops and fixtures not over 14 ft. above floor level shall be properly swept or otherwise cleaned every three months. There is no similar provision applying to other parts of the foundry, but we consider that, in addition to redecoration every

14 months, as required by Section I of the Factories Act, 1937, all accessible parts of the walls and the fixtures in these parts should be cleaned at least once during this period.

Removal of Dust and Dirt from Floors and Benches

8. Sections I (*a*) and I (*b*) of the Factories Act, 1937 require the daily removal of accumulations of dirt and refuse from floors, benches, staircases and passages and the weekly cleaning of workroom floors. There should be no difficulty about removing accumulations of dirt and refuse from benches, staircases and passages, but to enable the requirements about floors to be met, we consider it to be essential that firm and level surfaces should be provided and maintained. In our opinion, such conditions can only be secured if the floors are constructed of concrete, brick, tar-macadam, wood, steel or iron plates or other suitable material. Some foundries have already provided floors of this nature throughout the premises, and we are agreed that all floors in all parts of non-ferrous foundries should have prepared surfaces of the kind indicated above, unless it can be shown to be necessary to have a sand floor for any particular product in any part of a foundry.

We know that many foundrymen object to concrete floors because they anticipate danger from the splashes of molten metal that may result if it spills onto the concrete. Prepared floors need not necessarily be concrete, but in this connection we should like to draw attention to refractory concrete (*see* Appendix XIX). This material has been used for foundry floors and will stand the thermal shock resulting when molten metal spills onto it. It does not spall and we understand that metal does not, therefore, fly from it. The use of refractory concrete for foundry floors is relatively new and it warrants the serious attention of the trade.

It is important that the legal requirements of the daily cleaning of floors should be observed and in addition that all accessible parts of floors should be properly swept or otherwise cleaned at least once every day.

Methods of Cleaning

9. We consider that it is very desirable that vacuum cleaning plant should be used for removing dust and dirt from a foundry, because the spread of dust throughout the foundry is thereby avoided. We understand that this method is already being used successfully in some foundries. When sweeping is done, the dust should be damped before it is disturbed whenever it is at all possible to do so.

Recommendations

1. Non-ferrous foundries should be excluded from Part B of the First Schedule to the Factories (Cleanliness of Walls and Ceilings) Order, 1938. This will, in general, mean that the ordinary requirements for the washing, painting, whitewashing or colour-washing of walls and tops of rooms every 14 months will apply except as regards those parts over 20 ft. above the floor. In the meantime, full use should be made by H.M. District Inspectors of Factories of their powers to require the prescribed treatment of walls and tops of rooms, in accordance with Clause 5 of the Factories (Cleanliness of Walls and Ceilings) Orders, 1938 and 1948.
2. In addition to the periodical redecoration of walls and tops of rooms at least once every 14 months, all accessible parts of the walls and fixtures should be effectively cleaned at least once every six months. The

requirements of No. 10 of the Grinding of Metals (Miscellaneous Industries) Regulations, 1925, for the cleaning every three months of rooms in which cleaning of castings is done should continue to apply.

3. In addition to the daily removal of accumulations of dirt and refuse and the weekly cleaning of floors required under Section I of the Factories Act, 1937, all accessible parts of floors should be swept or otherwise cleaned daily.
4. All floors should be maintained firm and level and should be constructed of concrete, brick, tar-macadam, wood, steel or iron or other suitable material unless it can be shown to be necessary to have a sand floor at any particular part of a foundry.
5. The inside surfaces of walls should be smooth.
6. The use of vacuum plant for removing dust and dirt is strongly recommended.
7. Where sweeping is done, the dust should, wherever possible, be damped before it is disturbed.

GOOD HOUSEKEEPING

10. The term good housekeeping, as used in this report, is intended to include all means of attaining tidy and orderly conditions and avoiding obstructions and congestion. It is to be regretted that, in many foundries, little attention seems to be paid to the matter with the result that heavy equipment is dumped anywhere about the foundry and materials and gear of all kinds are scattered about indiscriminately on the floor, and the general impression is one of confusion and lack of system. In such circumstances it is impossible to keep gangways clear and the litter on the floors adds greatly to the hazards of the work and prevents proper cleaning. On the other hand, very different conditions are to be seen in foundries where the significance of good housekeeping has been fully appreciated. Mechanisation assists very materially towards securing desirable standards, but it is by no means an essential factor and some of the non-mechanised foundries are amongst the best kept.

We regard good housekeeping as of major importance because it facilitates the establishment of clean and safe conditions and improves the appearance of the foundry and, we suggest, has a beneficial effect on morale and production efficiency. The following recommendations are put forward as a general indication of practice which contributes towards good housekeeping; it is recognised that the actual methods adopted will necessarily vary to some extent according to the circumstances of particular foundries.

Recommendations

8. To facilitate cleanliness and tidiness, all work should be done in the most systematic manner possible and provision should be made for the orderly arrangement and storage of materials and equipment in suitable and convenient areas set apart for the purpose.

   In particular:

   (*a*) Dies, patterns, pattern plates, core boxes, core plates, grids, moulding boxes, loam plates, ladles and other heavy tackle kept inside the foundry should, if not in constant use, be stacked safely and in an orderly manner in an area apart from the working area.

(*b*) Dies, patterns, pattern plates, core boxes, core plates, grids, moulding boxes, frames, boards, box weights, loam plates and other heavy tackle in constant use should be arranged in an orderly and safe manner.

(*c*) Convenient racks, bins, etc. should be provided and used for the storage of miscellaneous gear and tools, such as runners, core irons, clamps, wedges, small hand tools, hangers, chills, shanks, buels, hand ladles, etc.

(*d*) Raw materials, such as sand or fuel, should be stored in bins, bunkers or tanks.

(*e*) Suitable receptacles should be provided and used for metal residues and suitable containers should also be provided and used for the deposit of scrap metal.

(*f*) Dross and skimmings should be collected and removed daily.

(*g*) All burnt core sand and waste products from shell moulding should be removed as soon as convenient after the castings have been knocked out and at least daily.

9. Clearly defined gangways of suitable width should be provided and should be properly maintained and kept clear. Recommendations regarding suitable width of gangways in new foundries are made in the section headed "New Foundries" and these should be adopted wherever possible in existing foundries also.

10. The following equipment should be provided with a clear level working area to assist operation:
    (*a*) Moulding machinery (including shell moulding);
    (*b*) Drying stoves;
    (*c*) Melting furnaces;
    (*d*) Gravity dies;
    (*e*) Pressure die-casting machines;
    (*f*) Centrifugal casting machines;
    (*g*) Heat treatment furnaces.

11. (*a*) All material and equipment kept out of doors should be safely stored or stacked in an orderly manner with proper roadways or pathways. Due care must be taken to dry any metal, stored in such a fashion, before it is fed into a melting furnace.

    (*b*) All outdoor roadways and pathways should be kept free from obstruction and if in constant use should have a prepared even surface.

12. Proper arrangements should be made for maintaining all equipment in a safe condition and defective equipment should not be used.

13. It is strongly recommended that the possibilities of using vacuum methods to control dust instead of any blowing off or dry brushing process should be investigated.

TEMPERATURE

11. Owing to the presence of furnaces, stoves, molten metal and die-casting machines, the main difficulty in many non-ferrous foundries is to prevent the temperature from becoming unreasonably high rather than to raise it to a

desirable level. Some parts of the foundries, however, for example dressing shops, are often remote from these sources of heat; and in foundries where casting is intermittent or is confined to the afternoon cold conditions may be, and often are, experienced on a winter's morning even in moulding shops if adequate measures are not taken to warm the premises. We think that the question of securing a reasonable temperature has not received the attention it should have done and that very often the means of heating provided are insufficient and unsuitable. For reasons given in the section on "Open Fires" we are agreed that no open fires should be used for warming a foundry. We also feel that coke fire mould dryers should not be used for this purpose even though they may be considered suitable for other purposes when used under properly controlled conditions. We think too that gas-fired mould dryers should not be used for space heating unless they burn town's gas and are constructed, maintained and worked in accordance with the latest standard specifications for domestic gas-burning apparatus designed to be used without flues.

12. We have carefully considered whether it would be practicable to suggest a reasonable minimum temperature which would be suitable for all types of foundries in view of their greatly varying structural and working conditions. Some are small and of brick construction, while others are large and lofty with corrugated iron walls and large openings—conditions which lead to enormous heat losses. The extent of the heat sources such as furnaces, stoves, die-casting machines and the number and size of hot castings left to cool in the foundry influence the internal temperature appreciably. In mechanised foundries casting is taking place throughout the day and the maintenance of a reasonable temperature during the morning is much easier than in foundries which cast in the afternoon only.

13. In some non-ferrous foundries such as die-casting foundries a large amount of radiant heat is present and this itself may make for unpleasant conditions while the furnaces and machines may induce a high air temperature. The presence of heavy concentrations of fume from fluxing or other processes may also require extensive ventilation so that the removal of hot air, with the fume, affects the convected heat in the foundry and may give rise to draughts. These matters are discussed in the sections on "Thermal Environment" and "Ventilation" but they should not be forgotten when considering temperature because they all exert their influence in determining whether the foundry is comfortable or not.

14. Provided that the question is not complicated by radiation and excessive air movement we agree that a temperature of 50°F. should be attained at working positions within one hour of starting work. We agree too that it would be unreasonable to insist on the installation of extra heating equipment for the purpose of raising the temperature to 50°F. on the comparatively rare occasions when the outside temperature falls below 30°F. and we feel that it would be sufficient on these occasions if an inside temperature of not less than 20°F. higher than the outside temperature was obtained. It is not intended that the minimum of 50°F. should be considered to apply in the case of a small number of men commencing early in the morning before the main work of the day is begun so long as the temperature is reasonable having regard to all the circumstances.

15. We do not think that we should recommend any particular type of heating but careful thought should always be given to the heat insulating properties of the building, to the design of the furnaces and the control of radiant heat and to

the suppression of dust and fume by ventilating equipment; and this section should be read in conjunction with the relevant sections to which reference has already been made.

Recommendations

14. Open coal or coke fires and coke fired mould dryers should not be used for the purpose of space heating.
15. Gas fired mould dryers should not be used for space heating unless they burn town's gas and comply with the current standards for domestic gas fired appliances designed for use without flues.
16. The temperature in the parts of a room where work is proceeding should not be less than 50°F. after the lapse of one hour from the time of commencing work subject to the proviso that if the outside temperature is less than 30°F. it would be sufficient if the inside temperature were not less than 20°F. higher than the outside temperature.

LIGHTING

16. It is now generally recognised that good lighting is a necessity not only to aid visual perception but also on account of its value as an amenity. This is particularly the case in some foundries where the dark nature and lack of contrast of much of the material handled, besides making seeing conditions more difficult, tends to give the premises a somewhat gloomy and uninviting appearance.

Section 5 of the Factories Act, 1937, requires provision to be made for securing and maintaining sufficient and suitable lighting, whether natural or artificial, in every part of the factory in which persons are working or passing. We think that full use should be made of daylight and the provision of ample means of natural lighting is a matter which should always have careful consideration in the design of new foundries and every opportunity should be taken to improve existing foundries in this respect. Artificial lighting also needs considerable improvement in many foundries both as regards intensity and distribution.

We understand that consideration is being given by the Ministry to a code of regulations under Section 5 of the Factories Act, 1937, and that this will be applicable to non-ferrous foundries.

Recommendations

17. It is important that the work in connection with the new regulations be completed as soon as possible.

USE OF COLOUR

17. The full benefit of good lighting in improving the appearance of non-ferrous foundries will only be experienced if the surroundings themselves are bright. In many industries there has recently been a marked trend towards the introduction of colour schemes for walls, ceilings and machinery. Light colours have generally been found preferable on account of their higher reflection factors, but where, as in foundries, the nature of the work is such that the walls are easily liable to become soiled a darker shade is often chosen for the dado with a lighter tone above. Stanchions, beams and surfaces are sometimes treated in brighter contrasting colours to give variety.

The colours of the materials normally used in non-ferrous foundries are uniformly drab and the adoption of colour schemes of decoration would introduce a note of cheerfulness which is badly needed. We understand that there is available a free advisory service on the use of colour and we hope that founders will take advantage of it.

WASHING FACILITIES AND ACCOMMODATION FOR CLOTHING

18. The provision of adequate and suitable facilities for washing and accommodation for clothing not worn during working hours is compulsory under the Factories Act, 1937. The Casting of Brass Regulations require a prescribed standard of washing facilities.

Although good provision is made in some foundries, this is a matter which needs a great deal more attention particularly in view of the fact that owing to the nature of many foundry processes it is specially desirable that facilities should be available for washing and for changing clothing. These considerations apply in particular to men engaged on hot and dirty work. It cannot be expected that the industry will attract the best type of workers unless good amenities of this kind are available.

Baths

19. We consider that sufficient and suitable baths should be provided for the use of workers engaged on hot, dirty or arduous jobs. Conditions vary so much in different classes of foundries that we are not able to make any definite recommendations as to the number of baths which should be installed. This is a matter which could, with goodwill, best be settled in individual foundries after discussion between the management and the workers. The majority of the baths already provided in foundries are of the shower or similar type in separate cubicles. This form of bathing accommodation has advantages on account of speed of use and economy of space and hot water.

Changing Rooms

20. Adjoining the bathrooms there should be a well warmed, lighted and ventilated changing room with sufficient seating accommodation. It should, preferably, be separated into two sections—dirty and clean—and we consider that two lockers should be provided for each man who changes his clothing—one for clean and the other for dirty clothing.

Wash-Basins

21. In addition to baths, hand wash-basins or equivalent washing facilities are, of course, essential. We consider that they should be provided on the general scale of one wash-basin for every ten persons employed at one time except in special cases, such as where the Casting of Brass Regulations apply. The actual needs at individual foundries will vary to some extent and it may not be necessary to adhere strictly to this proportion in all cases, in particular where a definite system of staggered hours is in operation.

Standards of Equipment

22. We wish to stress the importance of providing a really good standard of equipment. Warm water should be laid on and there should be adequate supplies of clean towels, soap and nailbrushes.

When washing facilities are installed in workrooms they are difficult to keep clean and we consider that they should be placed in separate washrooms wherever practicable. Bathrooms and washrooms should be properly warmed, lighted and ventilated and have impervious well drained floors. Square corners and ledges should be avoided and walls and partitions should be smooth and impervious so that they can be easily washed down. Glazed tiles, for instance, or other suitable glazed materials of light colour form an excellent surface for such rooms and help to make them attractive and encourage cleanliness and their proper use. We consider that such conditions represent good practice and urge their adoption as widely as possible.

Maintenance and Cleaning

23. All washing facilities, changing rooms and accommodation for clothing should be placed under the charge of a responsible person and arrangements should be made for their regular and frequent cleaning.

Recommendations

18. Sufficient and suitable baths, preferably of the shower or similar type situated in individual cubicles should be provided for the use of persons engaged on hot, dirty or arduous jobs.
19. Suitable wash-basins should be provided on the general scale of one for every ten persons employed at one time unless any particular section of the industry requires a more generous allowance.
20. Warm water should be laid on and adequate supplies of clean towels, soap and nailbrushes should be provided.
21. Baths and wash-basins should be housed in suitable rooms set apart for the purpose.
22. A suitable changing room should be provided adjoining the bathroom.
23. Lockers or other suitable arrangements should be provided for the accommodation of clothing and should be situated preferably in a separate room or rooms.
24. These amenities should be placed under the charge of a responsible person or persons, maintained in good condition and kept clean.

CANTEENS AND MESSROOMS

24. In some foundries excellent canteens serving hot meals are provided. There are, however, a large number of foundries without any canteen or messroom facilities and it is quite a common practice for meals to be taken in the foundry itself. We consider that provision, including facilities for warming food and boiling water, should be made for all persons who wish to remain on the premises at meal times to take their meals in clean and comfortable surroundings and that the practice of taking meals in the foundry itself should be prohibited.

Recommendations

25. Suitable canteens or messrooms should be provided for all persons who wish to remain on the premises for meals.
26. Where a canteen is provided provision should also be made for workers who bring their own food to enable them to take their meals in suitable surroundings.

27. Where there are no canteen services available a suitable messroom should be provided including adequate means for warming food and boiling water. It should be a separate room placed under the charge of a responsible person and should be kept clean.

28. Such proper facilities having been provided, the taking of main meals in workrooms should be prohibited.

WELFARE

25. Many foundries now provide really good washing, bathing and catering accommodation which is greatly appreciated and well used. It is essential for the success of these arrangements however that there should be the full co-operation of all those for whom they are provided and we feel strongly that full use and proper treatment are not likely to be obtained unless

(1) the amenities provided are of a really good standard ; and

(2) adequate arrangements are made for supervision and for regular and frequent cleaning by persons appointed for the purpose.

NOISE SUPPRESSION

26. One of our members, Mr. G. T. Hyslop, has made certain preliminary enquiries on our behalf in the United States of America, but little seems to have been done on the subject there and we know of no relevant British work. We therefore make no specific recommendations at this time but shall continue to give our attention to the matter.

DUST AND FUME SUPPRESSION

27. This phrase is used to include all the methods by which unwanted dust or fumes can be removed from the breathing zone of any operator. There are many such methods but they all fall into one of three broad groups:

(i) Elimination methods

(ii) Partial elimination methods

(iii) Control methods

(i) *Elimination Methods*

The elimination methods remove air pollution at source by changing the dust or fume producing process so that pollution never occurs. These methods are generally the most difficult ones to apply. They normally involve great technical skill and may frequently be possible only on the successful completion of long and involved research projects. On the other hand, they should not be ignored on account of the difficulties because wherever they can be applied they give the best possible results.

(ii) *Partial Elimination Methods*

Even when dust and fume cannot be eliminated altogether it is still desirable to eliminate as much as possible. There are two reasons for this. In the first place, most concentrations of dust or fume contain a mixture of substances some of which may be specifically dangerous to health and it is always worthwhile to eliminate these. This may involve a change of practice as new materials are substituted for the dangerous ones, and it may not even give any reduction

in the total concentration of the atmospheric pollution because the new materials may give as large a volume of pollution as did the old ones; on the other hand, non-dangerous pollution is preferable and the ultimate objective is no pollution at all. The second reason for the use of the partial elimination methods is simply to reduce the volume of pollution that must be controlled.

(iii) *Control Methods*

If dust and fume cannot be eliminated they should be controlled and there is no doubt that when the elimination methods have been pushed to the limit there will still remain ample occasion for the use of control methods.

These methods include the use of water, respirators, local exhaust ventilating systems and general ventilating equipment. Water has not proved successful in controlling fine airborne dust, general ventilation will limit the maximum to which a dust cloud will build up, but only remove the dust after it has passed through the breathing zone of the operatives, and respirators involve some personal inconvenience. They serve a vital purpose where they represent the only practicable means of dust control, but we still think that they should only be regarded as a first aid measure until such times as the control equipment can be applied to the machines or the processes, and not to the men. Local exhaust ventilation, therefore, provides the most important method for dust control, but all these different methods are discussed in the relevant sections of this Report.

General Considerations

28. At this stage of the work we can do no more than indicate certain broad lines of approach. We think it desirable, however, to stress the importance of eliminating dust and fumes and we hope that non-ferrous metallurgists and foundrymen will turn their attention to this matter. These matters warrant greater thought than is often given to them in the research stages of new processes; if the health and comfort of the operators could be given sufficient prominence in the research and development stage of every new process, much trouble and time could be saved in the foundries. Considerations of this kind might lead to the development of processes and the use of materials which did not give rise to obnoxious or dangerous fumes.

29. When dust and fumes cannot be eliminated, we consider it unsatisfactory to rely only on general ventilation methods to clear the air of a shop. Dust and fumes should be collected at source so that they do not pollute the general atmosphere of the foundry and general ventilation should only be regarded as a last resort when all other methods have proved impracticable. Much work has been done on the application of local dust suppression methods in the ferrous founding industry. Much still remains to be done and we hope that the non-ferrous industry will enter the research and development work which is progressing in this field.

30. The use of ventilating equipment to control dust and fumes will affect the temperature of the shop and will, therefore, influence the measures that are necessary to maintain a reasonable temperature. The matter is complicated by the presence of a good deal of radiant heat from certain processes and this should be borne in mind when designing equipment for the purpose of dust and fume control. The whole question of the thermal environment has given us some concern, and is discussed in the proper section in this report, but it should be remembered that air extracted for dust or fume control influences the thermal environment.

31. No specific recommendations can be made on the general considerations dealt with in this section, but examples of the various methods of dealing with dust and fumes are given in various sections of this report, and we have included this general discussion to indicate the nature and the complexity of the problem.

Recommendation

29. It is recommended that all schemes for the suppression of dust and fumes be designed on the basic principles set out in this section. Namely
    (i) that pollution be eliminated if possible,
    (ii) partially eliminated if complete elimination is not possible, and
    (iii) controlled only if the elimination techniques are not applicable.

THE MEASUREMENT AND OBSERVATION OF DUST

Dust Estimations—Absolute Methods

32. To enable conditions in foundries to be properly assessed, it is necessary to determine the quantity, nature and size of the dust particles in the air and to have for comparison some authoritative standard specifying the maximum concentrations of the various airborne particles which are regarded as permissible. Unfortunately, existing and reliable methods of sampling, counting and analysing dust concentrations call for expert knowledge and are laborious and involve very considerable expenditure of time. It is impracticable at present to undertake this work on a large scale in foundries generally, and in our view the development of some quick and accurate method of dust determination is highly desirable. We do not, however, envisage the setting up of maximum allowable concentrations of dust. We do not doubt that the development of a quick and accurate method of dust determination would be of great assistance in the practice of dust control.

Dust Estimations—Empirical Methods

33. In 1948 a rapid method of dust estimation was developed and the work was published[5] in September of that year. In addition, the method was also described in Appendix II of the second report of the Dust in Steel Foundries Committee[6].

The Moulding Materials Committee of the British Iron and Steel Research Association adopted the method as a standard technique and, in co-operation with the British Steel Founders' Association a general survey of conditions in Steel Foundries was begun and some of the results were published in 1951[7]. Dust estimations have also been done in iron foundries, and the experience gained showed that the method was accurate enough for the purpose for which it had been devised[8]. Following the suggestion made in the original work[4], the dust concentrations were reported in group numbers instead of particles per cubic centimetre. Later, in a statistical survey of two environmental studies, the use of group numbers was compared with the older method of reporting dust concentrations. This statistical work resulted in the conclusion that analysis of counts expressed in group numbers in which the dust concentrations between adjacent steps are arranged in geometrical progression, is probably the more satisfactory procedure for the establishment of dust levels[9].

The British Steel Casting Research Association has recently published a good deal more work[10], which has been done in an effort to obtain satisfactory dust

sampling equipment which could be used easily and conveniently for the purpose of estimating dust levels and variations in foundries.

Dust Observation and Photography

34. It is generally considered that dust particles less than ten microns* in diameter are the most dangerous, and these particles are invisible in ordinary lighting conditions. It was clear that great benefits would accrue if a method could be devised, by means of which moving clouds of very fine dust could be seen. The necessity for such a method was underlined by the fact that the new technique of estimation indicated that the provision of local exhaust ventilation for certain grinding wheels had not reduced the average dust concentration in the dangerous size range. A further unexpected result from the general surveys was that the dust concentration obtained from samples taken at the breathing level of men working pneumatic chisels, was sometimes high and sometimes low. The high results had been anticipated in certain cases, because of a known risk of silicosis. The low results could not be explained, however, unless they were due to the fact that the dust was invisible, and the instruments were sometimes used in the main cloud, and sometimes only placed near to it. It became apparent, therefore, that the reason for these results could be most easily ascertained if the dust clouds could be seen. In consequence, a member of our Committee, Mr. W. B. Lawrie, with the assistance of the staff of the Photographic and Reproduction Branch of the Air Ministry, investigated the problem and found that the dust clouds could be seen in a powerful beam of light, and further showed that they could be photographed in certain conditions.

35. When a beam of light is passed through a suspension of a finely divided solid in a liquid or a gas, the scattered light makes the path of the beam easily visible, especially if the experiment is done in darkness when the beam itself provides the only light source. It was found that dust clouds, which were quite invisible in ordinary lighting conditions, could be seen in the beam of a 2,000 watt lamp, if the cloud were observed at an angle of about 10° from the axis of the beam. It was also shown that the clouds could be recorded on a 35 mm. cinematograph film, if the camera were focused on the cloud looking up into the beam, so long as the glare could be avoided, and the work[11] was published in 1951. It has been shown that the very fine dust can be seen and photographed and that the method can be used in ordinary foundry conditions. It has proved itself to be a valuable practical instrument, and efforts are being made to determine the lowest particle size and dust cloud concentration that can be seen; this work is still proceeding.

36. The mere observation of the dust has been of great assistance in engineering developments and the photography has provided further information as the path of a rapidly moving dust cloud can be examined in detail. High speed cinematography has been used in certain cases to provide slow-motion pictures, but, in general, normal camera speeds have proved sufficient.

Plates 1, 2 and 3, which are some of the earliest photographs taken by the method, show the movement of dust from a pneumatic chisel, a stand grinder and a portable abrasive wheel—the last one with the conventional local exhaust ventilating system fitted and operating.

* 1 micron $= \frac{1}{1,000}$ millimetre $\simeq \frac{1}{25,000}$ inch

We have described these methods of dust estimation and observation so that the non-ferrous industry might be fully informed of the latest position. For the same reason, we have included much information which has accrued from recent research and development projects, and we hope that the industry will avail itself of this information, and use the new techniques to further its own development work where this proves to be necessary.

DUST AND FUME DISPOSAL

37. In various sections of this report, recommendations are made for the provision of local exhaust ventilation or the adoption of other suitable methods to prevent dust or fume given off in the processes from contaminating the general atmosphere of the foundry. Apart from the processes which have been specifically mentioned, there may be other operations carried on in the foundry at which similar measures should be taken, as, for example, where dust arises at mechanical sand handling plants or fumes escape from melting devices or casting processes not provided with hoods and stacks leading to the open air. General ventilation by itself should never be relied upon for this purpose unless local control is quite impracticable, although, as is stressed elsewhere in the report a high standard of general ventilation should always be maintained for other purposes.

With regard to the ultimate disposal of dust or fume removed by an exhaust system, it is undesirable for it to be blown directly into the open air. This has always been true, but it has recently been given the prominence it merits in the Beaver Report, and the consequential Clean Air Bill. We cannot recommend standards until we know the extent of the proposed legislation, but we would remind the industry that this matter is being discussed. It is often good practice to protect filtering equipment from the weather and house it in a separate room or shed which does not open into a workroom, and which is ventilated to the open air. The various filters and collectors which are commonly used in industry do not completely remove the very fine particles of dust which are liable to be inhaled, and for this reason the return of filtered air to a workroom is considered to be, in general, undesirable. Much dust can be created when dust collectors and filters are being emptied, and the adoption of sludging or other wet methods of disposal is practicable and desirable.

Recommendations

30. Exhaust systems should be equipped with efficient filters so that the dust or fume is not blown directly into the open air.
31. The return of filtered air to workrooms is, generally, undesirable.
32. Filters should be installed outside workrooms when possible.
33. The adoption of sludging or other wet methods for the disposal of dust from filters is recommended.

FOUNDRY PROCESSES

38. Many processes give rise to fume and dust in the foundry; various sections of this report refer to particular problems, but we have not been able to investigate the whole matter sufficiently closely to make specific recommendations in many cases.

Fumes from fluxing and de-gassing processes should either be eliminated or controlled, and we have referred to this matter in a separate section. Fumes from ladles in transit, or from which metal is being poured, are normally allowed to pass into the foundry atmosphere to be dealt with by general ventilation. This may be the only practicable method at the moment, but we should welcome new methods by which the fumes could be controlled at source. In this connection, we are greatly interested in the application of the low volume, high velocity system of exhaust to fumes produced when fluxing magnesium. We appreciate that this was a first experimental effort[18], but we hope to investigate the matter further in due course. During and after casting, some non-ferrous metals still fume and, here again, we have noticed with interest the application of the low volume high velocity system[18]. This, too, is early development work which we propose to investigate further. Finally, foundry atmospheres are frequently polluted by the products of combustion from furnaces. Generally, we think these should be taken to the open air by means of flues or hoods, although hoods are not always completely satisfactory. This matter is discussed in the section on the Thermal Environment in which we refer to a new furnace which was developed for us.

39. We think that each process should be considered separately, that dust and fume control should be applied at source before general ventilation is considered, and that where local control is impracticable, it may be desirable to segregate the particular process so that it does not pollute the whole foundry.

OPEN FIRES

40. Largely on account of their simplicity and general handiness, ordinary open fires have been used to some extent in non-ferrous foundries for various heating and drying purposes. By the term "ordinary open fire", we mean all ordinary coke, coal, wood or similar fires which are not provided with a flue system to take the products of combustion to the open air. Fires built in ladles, crucible furnaces or moulds for drying purposes, and all braziers or fire baskets used in other processes or incidental work, are thus included.

We have been confronted with problems arising from the use of open fires during our consideration of a number of the subjects dealt with in this report, and we have made recommendations under the relevant headings. These recommendations are based on the general grounds that such fires provide a source of smoke and fumes which are undesirable and which may, in certain cases, be injurious, particularly if several fires are in use at the same time. We are of the opinion that the elimination of open fires from non-ferrous foundries is necessary if the best possible conditions are to be obtained. We do not think that there are any circumstances in the non-ferrous founding industry in which the open fire must be used and so we recommend that their use should be discontinued altogether.

Recommendation

34. No ordinary open fire should be used for any purpose.

LADLE DRYING AND HEATING

41. We know that one of the easiest methods of drying and heating certain types of ladles is by the use of a wood or coke fire, either built in the ladle bottom or placed inside the ladle in a brazier. We appreciate that this has now

been prohibited in iron and steel foundries by Regulation 7(2) of the Iron and Steel Foundries Regulations, 1953, except when "adequate measures are taken to prevent, so far as practicable, fumes or other impurities from entering into, or remaining in, the atmosphere of the workroom". We think that the Regulation should govern non-ferrous foundries, so far as it is applicable, but we are of the opinion that there is little need to use this method of ladle drying in the non-ferrous industry.

42. We know that there is a considerable difference in the sizes of ladles or crucibles used in different non-ferrous foundries, because the industry is producing sand castings, shell moulded castings, chill castings, gravity die castings and pressure die castings, and although large ladles are needed, a preponderance of steel ring handle ladles and small crucibles carried in pouring shanks is used for producing small castings. In the case of large ladles, we consider that these can be dried satisfactorily by gas or oil burners, and this should preferably be done at special ladle drying stations. The small ladles, or small crucibles, which come mainly under the heading of steel ring handle, or shank crucibles are frequently dried in gas or oil fired furnaces, which are often used for this purpose only. A considerable number of these small ladles are also dried by using the exhaust from the bale out or tilting furnaces, and it is certainly common practice to keep them dry, after coating, by placing them near the furnaces.

We have heard of serious accidents, particularly when dealing with aluminium and magnesium alloys, which have been caused by men using damp ladles for molten metal. It is essential that all ladles be dry, and wet ladles should not, therefore, be left about the foundry where they may be picked up in an emergency. Recommendations have been made for fixed stations for drying ladles in iron foundries, but if this is contemplated in non-ferrous foundries, it is essential that the stations should be near to the furnaces and there must be no ladles stored within easy reach of them unless they can be guaranteed to be dry.

43. We fully appreciate that there may be some cases where very large ladles are used, and we think it essential that provision be made to extract from the working area any fumes which may be produced by the drying process.

Recommendations

35. No open fire should be used for the drying or heating of ladles and crucibles.
36. We strongly recommend the use of gas for the drying of ladles and crucibles, with the exception of small steel ring handle ladles or small crucibles which can be heated in special furnaces or dried by the normal method on melting furnaces.
37. Ladles or crucibles, after coating or daubing, should be kept in a dry condition so that there is no possibility of a damp ladle or crucible being used for molten metal.
38. A station for drying and storing ladles or crucibles, when not in use, is recommended.

MOULD DRYING

44. Large quantities of non-ferrous metals are cast in pressure or gravity dies, or in centrifugal machines, so that mould drying is not done in many non-ferrous foundries. Even in sand foundries, the use of shell moulding or the carbon

dioxide process will reduce the need for mould drying. Some sand moulds are, however, still dried or skin dried, and we think that open fires or other methods which emit smoke or fumes into the foundry should not be used.

45. Radiant heat produced either by electrical or gas appliances is being increasingly used in industry for drying purposes, but we have been advised that, although there are possibilities about this method, further progress will have to be made in the technique used before its merits as a mould drying agency can be fully assessed. Some skin drying of moulds has been done successfully by infra-red rays, but little is known as yet of the possibilities of deeper penetration, and there are said to be difficulties at present in connection with the drying of moulds having re-entrant cavities.

46. For certain sections of the non-ferrous industry, we cannot see any reason for the use of open coke fires, or even mould dryers, because it is only on very rare occasions that dry moulds are used, but even so these could usually be dried in a properly constructed mould drying stove. We know that a big proportion of the sand moulds are only skin dried and, although in the past various types of dryers have been utilised, we would strongly recommend that these moulds be skin dried by gas and air torches which have been found most efficient.

47. We fully appreciate that, occasionally, there may be large moulds or pit moulds to dry, which cannot be treated by the methods suggested. Open fires should not be used in these cases because the moulds can be dried by means of mould dryers. The use of mould dryers was recommended in the report of the Joint Advisory Committee on Conditions in Iron Foundries, although that Committee remarked that it had not proved possible to make exhaustive tests on the dryers before the publication of the report. These tests have, however, now been completed by the Technical Sub-Committee of the Joint Standing Committee on Conditions in Iron Foundries, and the work has been published in a report[23] which includes thirty-one recommendations on the use of mould dryers. We are in complete agreement with these recommendations which we have reprinted in Appendix I, and we think that the drying of large moulds and pit moulds should only be carried out in compliance with these recommendations.

48. Electric mould dryers are now available, but we have not yet been able to explore the circumstances in which they might be used. We are of the opinion, however, that the matter should be investigated because, other things being equal, they offer obvious advantages so far as foundry conditions are concerned.

Recommendations

39. No ordinary open fire should be used for mould drying.
40. Coke or gas fired mould dryers should only be used in compliance with the recommendations of the report on the drying of moulds by portable dryers. (*See* Appendix I.)
41. It is recommended that skin dried moulds be dried by means of gas and air torches.
42. Sufficient stove capacity should be provided to take all work which requires to be fully dried.

MOULD AND CORE STOVES

49. Most non-ferrous foundries have modern types of stoves for dealing with the drying of moulds, although it is recognised that only on rare occasions do the light alloy foundries use a fully dried mould. The biggest proportion of the

castings are produced from skin dried or green sand moulds. Non-ferrous foundries use core drying stoves of different types, but most of the larger foundries have modern types of stoves which are usually properly ventilated to prevent fumes from entering the workroom. We realise, however, that there are a number of foundries still using stoves which are heated by fires placed inside them or, alternatively, by the circulation of products of combustion from gas, coke or coal fired units. In these circumstances, ventilation is important. It should not be forgotten that, when some types of old drying stoves are heing charged or discharged, the fumes from the open doors of the stove may enter the workroom, and these fumes are often objectionable.

50. Many types of stoves are in use in the industry. Batch stoves are often used and in this design, after the cores have been baked, a rack is withdrawn from the store to be reloaded with another charge. The work is placed on a series of shelves or trays in the draw type stove which is arranged so that any particular shelf or tray can be withdrawn as required and another charge placed on it. In both batch and draw type stoves heat is maintained throughout the sequence of operations.

Continuous stoves are used to a large extent in mechanised foundries and may be of the vertical or horizontal type. In the former the cores are placed on trays which are conveyed mechanically up and down a tall heated chamber, the speed of the conveyor being regulated to ensure thorough baking by the time the cores have reached the discharge opening. In the horizontal type, the cores are conveyed through a heated tunnel by means of trays, similar to the vertical type, or racks which are pushed through the tunnel.

In all types of stoves objectionable fumes may arise (*a*) from the products of combustion of the fuel used, and (*b*) from the breakdown products of bonding agents, so that, unless special precautions are taken, considerable quantities of smoke and fume are liable to escape into the workrooms. It is also possible, if proper combustion is not obtained, that the plates and the cores may be covered with soot which can cause inconvenience to the core finishers.

Continuous stoves are usually so designed and worked that no substantial quantity of fume escapes into the foundry, but even so it is essential that every precaution be taken to keep the fumes under control. In the case of other types of stoves, it may be necessary to provide extraction systems to keep the fumes out of the workroom because the leakage from doors and the fumes from racks, bogies or cores that have been withdrawn can cause very serious trouble.

Recommendations

43. Every new mould or core stove should be so designed, constructed, maintained and worked as to prevent, as far as practicable, offensive or injurious fumes from escaping into any workroom during the period that the stove is actually being used for drying purposes.
44. Every attempt should be made to obtain similar conditions with existing stoves. Where it is found to be impossible, either in the case of a new or an existing stove, to prevent the escape of fumes, suitable arrangements should be made either by the use of mechanical exhaust ventilation or by other equally effective means to ensure that they are collected at their source and carried to the open air.
45. All stoves should, whenever practicable, be provided with suitable flues and stacks or other effective means to clear them of offensive fumes before they are discharged, or adequate local exhaust ventilation should

be provided to ensure that fumes do not enter the general air of the workroom, but are collected at the stove opening and carried to the open air.

46. Every mould or core brought into a workroom whilst it is giving off fumes of such a character and to such an extent as to be likely to be injurious or offensive to persons employed should be moved directly from the stove to a position under a hood provided with efficient exhaust ventilation to extract the fumes and carry them to the open air. All flues, doors, dampers, etc., should be properly maintained. All persons working at mould or core stoves should use all the means provided to prevent fumes from entering workrooms.

EASING OF CASTINGS

51. The design of some heavy castings is such that special precautions have to be taken, during the period of cooling after casting, in order to allow them to contract freely. In some cases sufficient relief may be obtained by the inclusion of "loam bricks" in the core or mould. In other cases it may be necessary to break certain parts of the cores or moulds or both. This process is known as "easing".

Easing may be carried out in a variety of ways. The method most frequently adopted is that of manual digging into the cores and breaking of the grates. This is a hot and dusty job and we strongly recommend that wherever practicable alternative means should be employed. It is possible, in some cases, to build chains into the core in such a way that, on withdrawing the chains by a crane at a suitable interval after casting, the core grates are broken and the casting is able to contract freely. Alternatively, the cores may be made collapsible, or partly so, by incorporating wedges in their construction, which can be withdrawn after casting. We suggest also that every effort should be made to arrange for "easing" to be done when no other work is being performed in the immediate vicinity.

CORE BINDERS

52. The use of various cereal or resin binders in the making of cores or moulds, which give off irritating or offensive fumes when baking or casting, is a problem common to ferrous and non-ferrous foundries alike. Having regard to a possible health risk, the Joint Advisory Committee on Conditions in Iron Foundries directed attention[1] to the need for finding substitute binders which would not have such disagreeable effects as the oil cereal binders commonly in use at that time. These included dextrin, starch, molasses and sometimes sulphite lye as green binder, while linseed or some other oil is used as a binder to give the baked strength so that the core can be moulded into and will retain any desired shape. The use of mineral oils as a substitute for linseed oil was not advised because of the suspected carcinogenic properties of some of them and the possibility of skin cancer to which, although the risk might not be great, it was thought advisable to draw attention.

53. The Joint Standing Committee on Conditions in Iron Foundries referred the whole question of core binders to a Technical Sub-Committee for special

investigation. Much valuable information is now available from the investigations undertaken, and the published results of the whole of the work to date are summarised in the Report of the Joint Standing Committee on Conditions in Iron Foundries[24-25].

Three lines of approach were examined:

(1) The control of fumes by the use of ventilating methods.

(2) The correct use of binders so as to minimise the fumes.

(3) The development of new binders which would not give off objectionable fumes.

The report of the Joint Standing Committee on Conditions in Iron Foundries[25] indicated that ventilating methods could be applied in suitable conditions, and the use of ventilated tunnels after casting on a conveyor belt in a mechanised foundry was quoted as an example. The Committee did not give much attention to this method because it was thought that exhaust ventilation might well be applied in suitable cases by conventional methods. The Technical Sub-Committee of the Joint Standing Committee on Conditions in Iron Foundries did, however, examine very carefully the methods of using binders and a Technical Report on Practical Methods of Reducing the Amount of Fumes from Oil Bonded Cores was published in 1950[26]. In view of the importance of this subject to the non-ferrous founding industry, we have reproduced the Recommendations from this Report in Appendix II.

The Sub-Committee also discussed the question of substitute binders, and the use of synthetic resins as an alternative to the oil cereal binders received considerable attention. Following the publication[27] of a survey of the subject by Mr. G. L. Harbach the Institute of British Foundrymen set up a Technical Sub-Committee under his chairmanship to continue the investigations. The findings of that Committee were published[28] in the proceedings of the Institute of British Foundrymen. The conclusions reached are to the effect that P.F. (*i.e.*, Phenolformaldehyde) resin produces the ideal of a practical and fumeless binder. Referring to the economic attractions of U.F. (*i.e.*, Ureaformaldehyde) resin and the fact that fumes from the cereal portion of the mixture are inevitable, whichever resin is used, the Report emphasizes that good ventilation, together with the use of minimum percentage binder and thoroughly baked cores are the most practicable means of improving conditions in foundries. At the present stage of these investigations these are reasonable conclusions which should receive the attention of everyone concerned in the non-ferrous foundry.

The introduction of shell moulding and the carbon dioxide processes are of considerable interest in this connection, the carbon dioxide process in particular approximating to a fumeless method of binding sand. We are investigating both these processes which are discussed in the relevant sections of this Report.

Quite extensive investigations were made by the Technical Sub-Committee of the Joint Standing Committee on Conditions in Iron Foundries on the question of the analysis of the fumes from core binders. These investigations were inconclusive, but finally a method of collecting the products of decomposition from binders in sufficiently large quantities for chemical analysis was proposed by a foundryman[29], and the same gentleman, Mr. W. M. Lord, has completed a survey of the literature on the subject up to 1955[30].

Recommendations

47. So far as is practicable local exhaust ventilation should be provided to control fumes from core binders at whatever stage of the process these fumes occur.

48. If the local exhaust ventilation does not completely control the fumes, it should be supplemented by good general ventilation.
49. Where local exhaust ventilation is impracticable, a high standard of general ventilation should be provided, but this should be regarded only as an interim measure and efforts should still be made to apply local control at the source of the fumes.
50. Core binders should always be used in compliance with the recommendations of the Technical Report of the Joint Standing Committee on Conditions in Iron Foundries on practical methods of reducing the amount of fumes from oil bonded cores. (*See* Appendix II.)
51. Every effort should be made to introduce new binders which will reduce or eliminate fumes.

SHELL MOULDING

54. This is a relatively new process and in consequence it is by no means easy to make final and specific recommendations at the present time. On the other hand, it is now in use as a production process and so we have discussed the matter in an effort to reach some interim conclusions which may be of use to the industry. In general we think that the process represents a definite advance so far as conditions are concerned, and we have no doubt that it will result in less dust in dressing shops because the very good surface finish that can be obtained, together with the close limits of size tolerance that are practicable, should reduce the amount of dressing to be done. At the same time there appear to be certain points in the process which require attention if the best conditions are to be obtained.

Dust and Fumes

Dust or fumes may appear at the following points in the process:

(1) The mixer.

(2) The dump box.

(3) Pattern spraying.

(4) Shells.

(5) Casting.

(6) Knock-out.

(7) Sand recovery.

There is less dust with the use of pre-coated sand.

The Mixer

55. If pre-coated sand is used there will be no mixing process in the foundry. Where sand is mixed with resin a large amount of dust may be produced.

Fine grained sands are normally used containing only very small amounts of clay. The sands are generally separated from natural deposits and may be water washed and air scrubbed during the process of separation. In consequence most of the fine material will normally have been removed before the sand is used for shell moulding. The amount of dust present from the sand is, therefore, likely to be much less than that from conventional dry sand moulding methods.

At the same time the shell process uses a smaller quantity of sand than the conventional methods of moulding so that this results in a still smaller quantity of dust.

The resin with which the sand is mixed is very finely ground and contains a proportion of hexamethylene tetramine. We have no size range analyses, but we do not doubt that the resin particles are small enough to become airborne. We do not know what possible physical effects the resin may produce, but we think that the matter might be the subject of a medical investigation.

Large quantities of dust are produced when mixing the sand. About one quarter of one per cent. paraffin may be added in order to reduce the segregation of sand and resin after mixing, and if this is added to the mixer it reduces the amount of dust produced when mixing. There is still, however, an appreciable dust cloud when charging the mixer.

We think that the mills should be provided with well fitting covers so arranged that the resin can be added without removing the cover. Local exhaust ventilation may be necessary at the openings of the chutes through which the resin is charged and the mill is discharged.

The Dump Box

56. Dust is produced when the dump box is charged and on each occasion when the pattern is removed after investment. This dust should be controlled by local exhaust ventilation.

The Pattern Plate

57. Fume is given off when the plate is sprayed and may also appear from the plate itself when it is not covered by the shell. This may be due to the emulsion sprayed on to prevent sticking, or it may be due to fragments of sand and resin adhering to the plate. Local exhaust ventilation should be applied to control these fumes. We are informed that these fumes, together with the vapours arising from the stripping solution, can produce headaches and lassitude in the operators.

The Shell

58. The plate is worked at about 250°C. and part of the shell reaches a similar temperature. Partial decomposition of the resin and the hexamine occurs and the fume produced may have to be controlled by local exhaust ventilation. This fuming ceases as soon as the shell is cold.

Casting and Knockout

59. Copious fumes are evolved on casting and at first these fumes burn. Later the flames die out and the products pass into the foundry atmosphere. We know neither the analysis of these fumes (which will differ from that of the low temperature decomposition fume given off when curing the shell), nor the effects they may produce in the operators, but the matter is worthy of a medical investigation. In the meantime we know that fumes are unpleasant and so we think that they should be controlled by local exhaust ventilation so that they do not pass into the general atmosphere of the foundry.

As the shell burns away there is no real knock-out process. Dust arises when the castings are removed, and it is desirable that this be controlled. Where the castings are removed at the pouring point, the exhaust ventilation used when pouring will serve to control this dust if so designed.

Sand Recovery

60. Used sand may be recovered after the resin has been burnt out. This process produces fumes which should not be allowed to pollute the foundry atmosphere. Suitable flue systems should be arranged to take the fumes out of the foundry.

Dermatitis

61. It appears, from practical experience in shell moulding, that the resins, in the hot conditions produced by the process, may cause skin irritation followed, in some cases, by a rash. Precautions must, therefore, be taken to maintain a high standard of cleanliness. The following recommendations in use in one foundry have greatly reduced the amount of trouble from skin complaints which was appreciable in the early days of tbe process, and have, in consequence, considerably improved the health and the efficiency of the department.

(1) Before commencing work in the morning and in the afternoon lanoline is used on the arms and bands. This is well massaged into the skin and not just smeared on.

(2) Moulders and assemblers must wash thoroughly at mid-day, stripping to the waist and washing away all traces of the material from the arms, hands, face, neck and chest.

(3) Each operator is supplied with a white boiler-suit which must be worn. These overalls are changed twice weekly by the foreman.

(4) Moulders are supplied with cotton gloves which must be worn next to the skin under the asbestos mitts provided. These cotton gloves are changed daily.

(5) The use of shower baths as often as possible is strongly recommended.

(6) Signs of skin trouble, or burns, are reported to the surgery immediately.

62. We are also informed that the Medical Officer of another foundry recommends that employees should wash with cold water before putting on the barrier cream in order to keep the pores closed, and that people who are susceptible to skin irritation, or who have had a previous history of skin trouble, should not be employed on this process.

Tidiness and cleanliness in the shop are essential. Open containers should not be used, as the fine resin and sand may cause contamination of the sbop atmosphere because of draughts if lids are not provided. Floors should be swept up if sand or residues are spilt, because the dust will become airborne as a result of the passage of men through the shop, if it is allowed to remain on the floor.

Recommendations

52. Local exhaust ventilation, or other suitable methods, should be applied to control the dust produced when mixing the sand. This may be facilitated if the mills are provided with well-fitting covers, and the dust, whicb is produced during tbe processes of charging and discharging the mill, should be controlled by local exhaust ventilation.
53. Local exhaust ventilation should be fitted so that the dust which arises from the dump box is not dissipated into the general atmosphere of the foundry.
54. Local exhaust ventilation should be provided to control the fumes which arise from the pattern plate, both when it is being sprayed, and when it leaves the stove with the shell.
55. The fumes which arise from the shell when cooling, should also be controlled at source.
56. The fumes which arise on casting should be controlled by means of local exhaust ventilation.

57. Suitable arrangements should be made to control the dust which arises when the castings are removed from the sand at the knock-out stage of the process.

58. If sand is recovered by burning out the resin, suitable flue systems should be arranged to take the resulting fumes out of the foundry.

59. In order to control dermatitis, full use should be made of such washing and bathing facilities as are provided.

CARBON DIOXIDE PROCESS

63. In this new process silica sand, of the type normally used for core making, is mixed with sodium silicate and moulded into shape. The mould is then treated with carbon dioxide which reacts with the sodium silicate to produce sodium carbonate and a silica gel which binds the sand grains together. Because water tends to soften the surface, mould facings may be suspended in spirits. The organic spirit is then burned off after the facing has been applied to the mould. The mould itself may consist of a hardened face only, backed by green sand from the floor, and in these cases, the amount of dry material in the mould is relatively small if the castings are knocked out quickly. Some difficulty is still being met with knock-out and de-coring in certain cases, because the sand moulds and cores set very hard. In consequence, efforts are being made to improve the breakdown properties by adding organic materials.

Fumes

64. Fumes may appear at two stages in the process. Organic solvents may be used when spraying the facing material on to the mould so that the solvent itself may vaporise and pollute the atmosphere, and the decomposition produced will pass into the atmosphere when the solvent is burnt off after the facing has been applied. We have no specific information as to the health risks which may result from this part of the process, but we think that it warrants further investigation, and there can be no doubt that the fumes should be controlled until they can be shown to be safe. Clearly, they will have to be controlled in any case if they appear in large quantities, or if they are objectionable in any way. From the viewpoint of the foundry atmosphere it is, of course, generally better to apply the wash by means of a brush or a swab. The second source of fume will be during the casting and the cooling period, and possibly, also, at the knock-out if organic materials are added to improve the breakdown properties of the cores. Once again, we have insufficient information as to the nature and toxicity of the fumes which may be produced. It appears that the materials which are being added are very similar to those already in use in core making, and we can only stress the need for further work, both chemical and medical, along the lines suggested by the Sub-Committee of the Joint Standing Committee on Conditions in Iron Foundries.

In any case, fumes which appear during or after casting, or at the knock-out, should be controlled by local exhaust ventilation where it is practicable, and if local exhaust ventilation cannot be applied at present, a high standard of general ventilation should be provided.

Dust

65. The sand normally used is core sand which will have been washed, and perhaps air scrubbed, in preparation. There should, therefore, be very little fine grained material in the sand. We think that new sand will be largely free from

dust, although, if the sand is reclaimed after knock-out or de-coring processes, this may no longer be true. In fact, if the de-coring processes involve the use of power-operated tools, the sand may well contain appreciable quantities of silica particles within the respirable size range.

Dust may be produced during the sand mixing process, and this should certainly be controlled if it appears in any quantity. If and when sand is re-used, it should be analysed for particle size range and chemical composition. This will be necessary to determine the amount, if any, of free silica within the respirable size range. It seems that the full silica content of the used sand in the small size ranges will depend on the nature of the process and the treatment that is necessary when knocking-out and de-coring. Clearly, if free silica is present in the respirable size range, the dust will have to be carefully controlled by local exhaust ventilation.

The dust produced at the knock-out operation should be controlled by one or other of the means suggested in the section on knock-out. We are in no position to assess the risk, because we know neither the size range, nor the chemical composition of the dust that might be produced. We think that this dust should be examined with a view to determining the health risk because this kind of information might well modify our conclusions.

One of the main difficulties encountered in the use of the process has been caused by the difficulty of breaking down the cores after casting. This difficulty will vary with the degree to which the core has been heated by the molten metal, and in extreme cases the sand may have fritted. We think, therefore, that the de-coring process should be considered separately from the knock-out. This process can sometimes be done without producing much visible dust, but we have no information as to the amount of fine dust which might be produced. We think this is of some importance because the small size range particles, which constitute the silica bond, may be separated from the sand grains at this stage. If this separation does occur, very fine silica may be present in the atmosphere, and if it is, the size range and concentration of this material should be determined.

Quite apart from the silica from the bond, if cores are so hard that they have to be broken down by mechanical tools such as pneumatic chisels, the sand grains will be comminuted into small particles, and this will give rise to the well-known risk from the use of these tools on castings bearing sand. It is still too early to make any dogmatic statements, but we think that local exhaust ventilation should be applied, as it is for dressing processes, if difficulty is encountered in de-coring, and we have no doubt that much more information is needed before we can recommend with certainty.

Recommendations

60. The fumes which arise from the use of organic materials in spirit washes should be controlled by local exhaust ventilation.
61. Fumes may be given off during casting, and at the knock-out process if organic materials have been added to the mould or cores to improve the breakdown properties. These fumes should be controlled at source by local exhaust ventilation.
62. The dust which results from the knock-out process should be controlled, and methods of doing this are discussed in the section on knock-out.

63. Dust which is produced by dressing operations should be controlled by ventilation or other suitable means. This whole subject is discussed in some detail in the section on dressing.

FLUXING AND DE-GASSING

66. A great variety of materials is in use for fluxing and de-gassing the wide range of alloys melted in the non-ferrous founding industry, and these materials produce fumes which differ considerably in chemical composition and in quantity. In consequence, we can do no more than draw attention to the problem in this first report on the industry and make certain general comments. We have no doubt that the matter should be investigated fully when each group of alloys would have to be considered separately. We do not know the chemical composition of the fumes which may be given off, and so we are in no position to seek medical advice as to the health risk, if any. In this connection, we have completed a very preliminary examination of certain aspects of the matter, but no discussion of the work is possible in these very early stages.

We are quite sure, however, that in many instances, fumes are evolved in such quantities as to become thoroughly objectionable, even though they may not be specifically dangerous, and in these cases, they should be controlled.

67. The fumes can be dealt with in one of three ways. They can be eliminated by changing the process, they can be reduced by a more judicious use of the materials that cause them, or they can be controlled by local exhaust ventilation after they have been allowed to form. The first method is always the best, but, commonly, the most difficult. In the sections of this report which deal with the thermal environment, and with ventilation, reference is made to one particular process in which de-gassing has been eliminated, and fluxing has been almost eliminated. In this particular case, aluminium was being cast in pressure die machines, and the only flux now in use is a small amount which may be added between shifts. We think that a determined effort should be made to avoid the use of fluxes and de-gassing agents when casting aluminium in pressure dies. Many aspects of the matter will have to be considered, and we think that, in the past, the question of fluxing has been examined on too narrow a basis. For instance, while we appreciate that fluxing and de-gassing are essentially metallurgical matters, we cannot fail to realise that the metal temperature affects these processes. This temperature is, in turn, controlled by the design of the runner system. With an incorrect gating system, the metal must be cast at a higher temperature, and this necessitates the use of more flux. Fluxing can, therefore, be influenced by such matters as die and runner design, and even when the use of fluxes cannot be avoided altogether, the resultant fumes can often be modified, both in composition and in quantity, by proper gating.

Conditions are improved when nitrogen de-gassing is substituted for chlorine de-gassing, and this should always be done if it is possible. We think that there is opportunity for improvement generally along these lines, if founders turned their attention to the discovery of innocuous fluxes and de-gassing agents which could be used instead of materials which are known to produce obnoxious fumes.

68. Whenever the fumes are evolved, they should be controlled by efficient local exhaust ventilation systems applied as closely as possible to the point of origin of the fumes. Here again, it is not yet possible to recommend particular methods, but we have no doubt that the various processes, from which the fumes may escape, will have to be dealt with separately. We are interested in the attempt to

apply the low volume high velocity exhaust system to the control of fumes which resulted from fluxing in a furnace[18], but this is very early experimental work, and a good deal more investigation will have to be completed before specific recommendations can be made. Fumes may also be given off as the metal is transferred from the furnace to a ladle, and this part of the process, too, requires a good deal of thought if efficient local exhaust ventilation is to be provided. Another matter which is perhaps still more difficult, is the control of fumes from ladles in transit. We have no doubt that efficient local exhaust ventilation should be provided for ladles which are being carried about in the foundry during the period in which the metal is fuming, but so far as we know, no successful system has yet been devised for this work. The normal method is to rely on good general ventilation, but as we have discussed elsewhere in this report, this method is not altogether satisfactory. Finally, fumes resulting from fluxing may still be emitted during the casting process, and, indeed, after casting has been completed as the moulds cool. The normal method of dealing with these fumes in the past has been to use a high standard of general ventilation, but we do not think this entirely satisfactory, and we were very interested in the experimental work which had been done in an effort to apply the low volume high velocity exhaust system to the casting and cooling periods[18]. We cannot, as yet, possibly recommend specific methods for particular cases, but the whole matter of fume control is referred to in many sections of this report where the latest experimental work has been described.

Recommendations

64. Fluxing should be eliminated wherever possible. We have shown that de-gassing can be completely eliminated, and that fluxing can be almost eliminated in the case of one aluminium alloy cast in pressure die machines, but we think that the whole question should be examined on the widest possible basis.
65. Where fluxes must be used, efforts should be made to discover materials which produce innocuous fumes in the smallest possible quantities.
66. Nitrogen de-gassing should be substituted for chlorine de-gassing wherever possible.
67. Care should be taken to use the smallest possible quantities of fluxing or de-gassing agents when these produce fumes.
68. Fumes from fluxing or de-gassing should be controlled by efficient local exhaust ventilation. Where this is not practicable at present, a high standard of general ventilation should always be maintained.
69. The fumes evolved by fluxing should be analysed in order to determine the health hazards. This will obviously be a protracted and difficult matter, but we are satisfied that very definite efforts should be made to obtain the information.

THE THERMAL ENVIRONMENT

69. Discussions on the question of radiant heat drove us to the conclusion that experimental work was necessary in order to obtain some measure of the thermal conditions existing in the industry at present, and so we remitted the problem to out Sub-Committee. It was evident that nothing more than a preliminary survey

could be undertaken, but because we considered that factual information was essential, we agreed that a number of foundries should be investigated in an attempt to acquire a general cross section of the industry.

The work was undertaken by Mr. W. B. Lawrie, who is a member of our Committee, and Dr. D. Turner, of the Environmental Hygiene Research Unit of the Medical Research Council. The foundries chosen covered a wide field of metals and non-ferrous practice, and many types of furnaces were investigated. The purely thermal work indicated that there was a definite need for remedial measures, and it was obvious that the problem could be dealt with, either along the conventional lines when the operators would be shielded from the effects of the radiant heat, or by an investigation of melting practice in an effort to design furnaces which would not emit radiant heat. It is clear that heat from furnaces which causes personal distress is also a source of financial loss, as the fuel which supplies this heat has been purchased to melt the metal. In consequence, Mr. A. Eyden, the Chairman of our Sub-Committee, and Mr. A. Edwards, the Chief Engineer of a foundry, joined the original investigators, and the four workers proceeded to construct thermal balance sheets on certain furnaces. For various reasons much of the early work centred around bale-out furnaces, and it was found by the workers that one particular bale-out furnace was working at a fuel efficiency as low as 13·55 per cent. This is so low that it led to the consideration of the possibility of designing other types of furnaces which might replace the bale-out furnace completely in the foundry in question. The workers have now completed the first step in the project, and the work has already been published[31].

70. It is obvious that the great variety of alloys melted in the different circumstances of the non-ferrous industry, presents a whole series of separate problems, each of which will have to be considered separately. As a first step, however, a new reverberatory furnace, melting 600 lb., has been constructed and put to work in a pressure die-casting foundry and has shown an efficiency of 31·9 per cent. The furnace is a continuous melting unit which replaced two bale-out furnaces and melted aluminium for a pressure die machine. The increased fuel efficiency is a matter of some importance, particularly as the metal melting losses remained as low as 0·81 per cent., but from our point of view, the most interesting feature of the work was that when eight of these furnaces had been put to work in one foundry, the mean radiant temperature fell to such a low figure that the problem of radiant heat no longer existed.

The thermal environment is affected by the amount of ventilation in the foundry, as well as by the presence of furnaces, and the ventilation range is often determined by the need to remove fumes caused by fluxing and de-gassing. The use of the new reverberatory furnaces led to an examination of the need for fluxing and de-gassing, and this, in turn, drew attention to questions relating to the design of runner systems for the dies. These matters, of course, are not immediately concerned, but they do affect the thermal environment, and so they are discussed in the published work to which reference has already been made[31]. They are also discussed in the relevant sections of this report, and an effort has been made to draw the whole of this complicated matter together in the section entitled "Ventilation".

The work which has been undertaken for us by our Sub-Committee is by no means completed, and so we can indulge in no dogmatic statements or recommendations at this stage. We know now, however, that a reverberatory furnace can be used for the melting of aluminium for pressure die-casting machines.

We know, too, that the use of such a furnace will give a fuel efficienty of about 30 per cent., whilst that of bale-out furnaces is about 15 per cent. In addition, the reverberatory furnace can be so designed that it will improve conditions in the foundry to such an extent that there is no further heat problem. At the same time, it was shown that aluminium could be melted for use in pressure die-casting machines without de-gassing at all, and without the use of fluxes, apart from a very small addition between shifts in a plant which was running continuously round the clock. This work on melting methods will influence our work on the control of fumes, and we think that the implications from this early research and development project should be considered quite seriously throughout the industry. Work is still proceeding and so we can make no final recommendations, but we are quite convinced that a determined effort should be made to avoid the use of the bale-out furnace as it is now known. In order that the industry shall be fully informed of the position that we have now reached, we have included a summary of the work to date in Appendices IV and V.

KNOCK-OUT

71. "Knock-out" was defined in the Garrett Report as "a term used to describe the various ways of removing castings from sand". The Report then proceeded to indicate the three main forms of knock-out as (*a*) the mechanised plant where the boxes are taken through a central grid; (*b*) the non-mechanised light foundry where the boxes are knocked-out at the pouring positions as quickly as possible after casting, and all over the foundry floor, and (*c*) jobbing and heavy foundries, where the knock-out is done at irregular intervals and anywhere on the foundry floor. We agree substantially with this division of the process, but we think that some modification may be necessary in the case of shell moulding foundries, even if these are mechanised. The reason for this is the speed with which the binder burns out of the sand. In consequence, the mould disintegrates so quickly that it is doubtful whether it could be taken to a central knock-out point. In any case, there is no true knock-out as a separate process, because the mould rapidly falls away from the casting. It appears, therefore, that shell moulds do not fall within the classification of the Garrett Report, and we have referred to the matter separately in the section of this report which deals with shell moulding.

72. Since the publication of the Garrett Report, a good deal of attention has been given to the problem of dust control at knock-out operations, and as we have not had sufficient time for practical work in non-ferrous foundries, we think we should limit ourselves to an indication of the scope of this work, although we have included in Appendix VII a description of a new knock-out system not previously published.

The Foundry Atmospheres Committee of the British Cast Iron Research Association first discussed this matter, and in view of its complexity, set up a Knock-out Panel. The work of the Research Association on air flow at down draught and side draught grids has now been published[32], as also has the report of the Knock-out Panel[33] (Appendix VI). These publications give the present position which is not greatly different from that described in the Garrett Report.

Mechanised Foundries

73. The Knock-out Panel is in agreement with the Garrett Report that dust control is much easier in mechanised or semi-mechanised foundries where boxes can be taken to one or more permanent positions for knock-out. In these

circumstances, local exhaust ventilation can be fitted to these knock-out positions. The Panel rates the various methods of applying ventilation in the following order:

(1) Fully enclosed knock-out.

(2) Side draught.

(3) Down draught.

(4) Up draught.

(5) General ventilation.

(1) *Fully Enclosed Knock-out*

Complete enclosure of the knock-out is considered to be the ideal method. We have no doubt that this is true, and in spite of the mechanical and technical difficulties which are self-evident, we can but agree with the Panel that much more thought should be given to the design of totally enclosed knock-outs on mechanised plants using standard sized boxes or snap flasks. The ideal method would, of course, be a completely mechanical knock-out at which no man need work. The whole operation could then be done inside an enclosure, and dust control would be simple. The design of such a knock-out would present great practical difficulties, but the advantages which would accrue are so obvious that we hope that foundrymen, whose work lends itself to this kind of treatment, will make a real effort to devise the necessary equipment.

We think that the ordinary mechanised knock-out grid might well be largely enclosed in suitable cases, so that the opening in the enclosure is no larger than is needed for the passage and manipulation of the boxes and castings. This would give better dust control than is often achieved by means of a hood, and would represent a considerable step in the right direction.

In cases where a permanent enclosure is not practicable, a movable enclosure might be considered. An example of this was given in a paper[34], presented to a British Cast Iron Research Association Conference in 1951. The knock-out grid in this method is left open until the moulds have been put on to it. The hood, which is operated by compressed air, is then pushed over the grid, and exhausted through two openings in the floor which are automatically connected as the hood comes into position. The method has now been developed in this country, and is referred to in the discussion on a paper presented at a British Steel Castings Research Association Conference held in 1955[35].

(2) *Side Draught*

Side draught systems are considered next in order of merit, and it is suggested that plants should be designed so as to have one side of the knock-out grid free for the side draught hood. This hood should slope so as to overhang the knock-out grid as far as is practicable, and should be mounted on the side of the grid which is opposite to the working position of the men. This will ensure that the men never work between the exhaust hood and the grid. The suction opening should be above the level of the top of the boxes being knocked-out.

(3) *Down Draught*

This is a common form of local exhaust ventilation, but the Panel indicate the very grave restrictions which must be observed if good dust control is to be achieved. They suggest that it cannot successfully be applied to boxes over 10 in. in height, that they should not exceed one-fifth of the total area of the grid, and that the grid itself should not exceed 16 sq. ft.; even then, the box must be placed centrally, and the sand to metal ratio must be such that only a thin layer of sand nearest to the casting face is dry. This means that dry sand boxes should not be knocked-out on a down draught system.

Within these limits the system may control the dust, but the limits themselves obviously prohibit the use of the system in very many cases.

(4) *Up Draught*

The Knock-out Panel point out that up draught hoods may collect the rising fumes, and remove them from the foundry. They may, therefore, protect many of the operatives in the building. On the other hand, they will not protect the knock-out workers as all the dust and fume must be taken past their breathing level before being extracted. They are, therefore, not recommended.

Heavy and Jobbing Foundries

74. The problem of dust control in heavy and jobbing foundries remains essentially unchanged since the publication of the Garrett Report. This kind of work is, perhaps, not typical of the non-ferrous industry, but we think it warrants certain general remarks.

In heavy foundries, castings may be made in pits, and so far as we know, only one effort has been made to provide ventilation for a heavy pit. This was in Sweden, and the method was referred to in the British Cast Iron Research Association Conference held at Ashorne Hill in 1951[34]. More information is needed before the system can be appraised. Efforts are also being made in this country to avoid pit moulding, and make the casting in a box so that the difficult problem of dust control at a pit does not arise. Work of this kind was described at a British Cast Iron Research Association Conference held in Harrogate in 1955[36].

Where the full pit method is not needed, heavy work may be "bedded-in". In this process the top part of the casting is in a box and the bottom part in the floor. This method gives difficulties of dust control, which are almost equivalent to those met at a pit, because the dust forms as the casting is lifted from the floor. The Knock-out Panel suggested that portable hoods should be used for this kind of work, but so far as we know, no experimental work has yet been completed.

Finally, heavy work may be done in boxes. These boxes should, wherever possible, be taken to a central knock-out point. If they are then knocked-out on a heavy grid, dust control methods can be applied. If they are knocked-out at the place where they were cast, dust control becomes difficult, although the portable hoods already suggested may provide a practicable solution to the problem.

Light Foundries

75. Light foundries, where the knock-out is done all over the floor, also present a problem in local exhaust ventilation which has not yet been satisfactorily solved, and the recommendations of the Garrett Report remain valid. There is

no doubt that dust and fume are much more easily controlled when the knock-out can be done at one or more fixed points, and this remains the ideal, although it may not always be practicable in existing foundries.

One further point must not be overlooked in non-ferrous foundries. This section deals with dust and fume control at the knock-out, but many non-ferrous metals fume in the ladle and during and after casting. These fumes may exceed those given off at the knock-out, so that while the latter must be controlled, the former also present a formidable problem in light foundries casting all over the floor. This separate problem is discussed elsewhere in this report.

General Ventilation

76. As the report of the Knock-out Panel points out, general ventilation only limits the build-up in atmospheric dust concentration and so affords no immediate protection to the men working close to the source of the dust. It should only be used, therefore, when no local control of dust or fume is possible, and it should always be remembered that it provides no final and satisfactory solution to the problems of dust and fume control. This matter is discussed more fully in the section on ventilation.

Recommendations

Applicable to all foundries

70. *Ventilation Methods*

It is recommended that, when knock-out ventilation systems are designed, the various methods of ventilation be considered in the following order of merit:

(i) fully enclosed knock-out
(ii) side draught
(iii) down draught
(iv) up draught
(v) general ventilation.

71. *General Ventilation*

Special attention should be given to the maintenance of good ventilation in the vicinity of all knock-outs.

72. *Damping*

As and where necessary, and wherever practicable, water should be used to allay dust at all knock-out operations.

73. *Cleanliness*

Special attention should be given to cleanliness in the vicinity of all knock-outs.

Applicable to special types of foundries

74. *Mechanised foundries*

Effective and suitable local exhaust ventilation should be provided and maintained at the knock-out.

75. *Heavy and Jobbing Foundries*

All knock-out operations should be done:

(*a*) in an area at which effective and suitable local exhaust ventilation is provided; or, if this is impracticable,

(*b*) in a separate room or in a separate part of the foundry effectively partitioned off and provided, as far as practicable, with effective and suitable local exhaust ventilation, and a high standard of general ventilation; or, where it is not possible to comply with (*a*) or (*b*),

(*c*) at a time when no moulding is proceeding, in the same room. This recommendation is not intended to apply as regards occasional emergency moulding or break-down work, or occasional knock-out of green sand castings urgently required.

76. *Light Foundries*

(*a*) *Green Sand Foundries in which the Knock-out is done on the same day as the Cast*

Compliance should be made, wherever practicable, with recommendation 75 (*a*) above. Where this is impracticable, special attention should be given to general ventilation.

(*b*) *Other Light Foundries*

There should be compliance with recommendation 75.

77. *Alternatives to Local Exhaust Ventilation*

Where other methods can be shown to be equally effective as local exhaust ventilation in preventing dust, fume or steam from entering the general atmosphere of a foundry, these methods should be acceptable.

DRESSING OPERATIONS

77. In the Garrett Report, the term "dressing" is taken to include stripping and other removal of adherent sand, cores, runners, risers, flash, etc., from castings and the production of a reasonably clean and smooth surface. The methods employed vary with the weight, size and nature of the castings, and may involve the use of picks, bars, wire brushes, hand hammers, blasting apparatus, rumbling barrels, grinding wheels, cutting equipment and occasionally pickling tanks. We think that these definitions apply to non-ferrous foundries and we agree that conditions in many dressing shops are unsatisfactory, particularly with respect to dust control. Many non-ferrous castings are made in metallic dies, so that there is no adhering sand, although dust will be produced if grinding wheels are used on these castings. Other non-ferrous castings are made at relatively low temperature, so that, even when they have been cast in sand moulds, there will be a good deal less adherent sand than is the case in ferrous castings. On the other hand, we have no doubt that dressing processes often produce dust in the non-ferrous industry, and we think that this dust should be controlled. We have not had sufficient time to explore this matter, although some preliminary dust counts have been made, but a considerable amount of work has been done on dust control in the dressing shop since the Garret Report was published. We appreciate that this work was done specifically with the ferrous foundry in mind, but we are certain that much of it can be absorbed into non-ferrous practice and we think that this should be done as quickly as possible.

Dressing Benches

78. Small work can be done on benches which may be fitted with local exhaust ventilation to control the dust, and the earliest experimental work that was done showed that an air curtain, correctly applied, might increase the efficiency of dust control and, at the same time, reduce the air volume needed[11].

The Pedestal Grinder: the 14-in. Diameter Wheel

79. One of the first results of the dust elimination technique was to show that the conventional exhaust systems fitted to stand grinders were not always satisfactory[11]. This work was done on a 24-in. diameter wheel. The Foundry Atmospheres Committee of the British Cast Iron Research Association therefore decided that a 14-in. diameter wheel should also be investigated. It was found that the smaller wheel showed similar characteristics to the 24-in. wheel, and so a new system of dust control was designed for the 14-in. wheel. The new design dispensed with the conventional exhaust system and controlled the dust hy means of relatively high speed air movements which were applied externally to the wheel hood. In consequence, the system hecame known as the external exhaust system. This system gave a high standard of dust control[13].

The Pedestal Grinder: the 24-in. Diameter Wheel

80. When the work on the 14-in. wheel had been completed, the Foundry Atmospheres Committee decided that the method should be tried out on a 24-in. diameter wheel. The investigators finally developed a unit in which the new external dust control system was combined with the existing conventional system, and this unit was known as the combined system[14]. Laboratory tests, once again, showed a very high standard of dust control. The experimental work which led to the completion of the two research and development projects is summarised in Appendix VIII and Appendix IX.

The Portable Grinder

81. The portahle abrasive wheel has often been used without dust control of any kind. Light castings could he worked on a bench fitted with local exhaust ventilation, hut this is not always convenient, and may he impossihle, with heavy work. In consequence, research and development work was started in an effort to provide some suitable means of dust control. This has resulted in a new integral system which uses a very low volume of ventilating air at a very high velocity. The method, which represents a completely new approach to the problem, gave good dust control and was puhlished in 1954[16]. The first successful prototype enahled the dust to he controlled through a hood which enclosed much of the wheel. Later, to increase flexibility, the hood was cut down so that it only enclosed ahout half the wheel and the dust control was maintained[17]. Finally, efforts were made to control the dust produced from wheels running without hoods and an extractor head was developed which gave good dust control and could be used on open wheels[20]. Development work is still proceeding as experience is being gained in dressing shops, but these methods are now available for the control of dust on portahle grinders and so we have included a summary of the experimental work which led to them in Appendix X.

The Bench Grinder

82. The work on the portahle grinder provided a local exhaust system which extracted only 25 cu. ft. of free air per minute at a vacuum of 5 in. of mercury, with a calculated dust velocity of the order of 12,000 ft. per minute. As the low air volume had ohvious advantages, the investigators adapted the method for use on an 8-in. diameter hench grinder. The results have already heen puhlished in detail[17], and hoth the illumination technique and the dust counts indicated a high level of dust control. We have included a description of this machine in Appendix XI.

The Portable Surface Grinder

83. The low volume or high velocity system was then applied to a portable surface grinder, and a new exhaust system, which forms an integral part of the machine, was developed[18] and gave very good control of the dust produced when grinding. Later work has shown that the full circumference of the wheel need not be covered by the duct[20], and equivalent dust control has been achieved with a section of the wheel exposed. This allows greater freedom in working. We have included a summary of the work on this machine in Appendix XII.

The Swing Frame Grinder

84. An early attempt to fit exhaust ventilation to a swing frame grinder was published in 1951[37]. Later, the British Steel Castings Research Association developed an integrated system, which used 900 cu. ft. of free air per minute[38 39]. The new low volume high velocity system was then applied to the swing frame grinder[18], and finally it was adapted for a transverse wheel[20]. The British Steel Castings Research Association have also developed a combined booth and integral exhaust system, which was published late in 1955[39]. Swing frame grinders incorporating these systems are now on trial in works conditions. We have included in Appendices XIII, XIV and XV short descriptions of the various methods that have been used in order that the non-ferrous founding industry might be fully informed of this matter, although we appreciate that there may not be a lot of swing frame grinders in use in the industry.

The Pneumatic Chisel

85. Pneumatic chisels have been used without any method of dust control, although in cases where the work is small enough to be dressed on the bench, the bench itself may be fitted with local exhaust ventilation[11]. This is impossible on heavy work, and appreciable dust clouds may be generated if the castings carry adherent sand.

The recent work has resulted in a new approach to the problem, and the development of a low volume high velocity system has eanbled local exhaust ventilation to be applied to the pneumatic chisel. The exhaust air can be extracted over the operator's hand or over his glove[16], through a hollow chisel[16], or through a suitable duct which is external to the chisel[20]. The method, which gave good control of dust of the respirable size range, was originally published in 1954[16], when the ventilating air was extracted either through a pipe held over the operator's glove or through a hollow chisel. Later work has resulted in a rubber sleeve which can be fitted to a standard chisel. This sleeve is provided with ducts, which are arranged in pairs above and below the face of the chisel, so that the ventilating air can be carried through them and will control the dust of respirable size range from both the back and the frout of the chisel. Where large quantities of dust have to be handled, a conical extension duct, which is made of rubber, can be fitted over the sleeve[20]. The system, which is now in use in industry, is described in Appendix XVI of this report.

The Wet De-coring Bar

86. We have noticed with interest the wet de-coring bar which was developed by a member of the staff of the British Cast Iron Research Association. A collar mounted on a bar carries four jets which project a spray of water along the bar in such a fashion that it is thrown beyond the end of the bar. This spray wets a sand core before the bar strikes it, so that no dust is raised when the core is

broken. The device has only been applied to hand bars, and the de-coring process may not be as common in non-ferrous foundries as it is in the ferrous trade. We think, however, that the matter warrants the attention of any non-ferrous foundry where sand cores are removed by means of hand bars.

This method of dust suppression relies on the elimination of the dust by wetting the sand, and it should be noted that it is a method of dust elimination, rather than one of dust control. Once again, in order to keep the industry fully informed, we have included a brief description of the de-coring bar in Appendix XVII.

Dust Control by Water: Water Sprays

87. We are informed that many attempts have been made to control airborne dust by means of water, but that it is still not a very satisfactory method. If a process can be done wet, or moist, or in solution, or suspension, there will be no dust. This, however, is a method of dust elimination and not a dust control technique, and the two different methods of dealing with dust should not be confused. Once an atmospheric dust cloud of the respirable size range has been allowed to develop, it is practically impossible to bring it under control by means of water.

The British Cast Iron Research Association has done some experimental work on wet portable grinders. In one case, the water was pumped through the wheel from a hollow shaft[40]. The point of contact of the wheel with the work was, therefore, constantly fed with water. In a second method, the water was simply sprayed onto the wheel[41]. The Joint Standing Committee on Conditions in Iron Foundries, however, remarks[42] that fine dust leaks through the water spray and that the systems will have to be improved if they are to be accepted as a satisfactory solution to the problem. In this connection, we have also noticed some experimental work on wet rock drills as used in mining practice[16]. Here again, early work seems to indicate that fine dust within the respirable size range may penetrate the water, even when it is applied in quantity and at pressure.

General Considerations

88. To obtain the best conditions, dust from all dressing operations should be suppressed at its origin, either by local exhaust ventilation, or by some other equally effective means, and this should be the principal aim. We have included in this report much of the recent research and development work which was directed to this end and the results of this work should, we think, be incorporated into non-ferrous practice as quickly as possible. Further research and development projects should then be started where these prove to be necessary. In order to facilitate the application of the various methods of suppressing dust, and to make conditions generally tidier and more orderly, all dressing operations should be concentrated in an area of the foundry set apart for the purpose in which no other processes are carried on. More than one such area may be required in a large foundry, but the number should be kept to a minimum.

While every effort should be made to suppress the dust at its source, it is recognised that this may not be practicable in all cases, and alternative measures for improving conditions have then to be considered. It is recommended that all dressing operations at which complete control of dust is not obtained should be segregated from the rest of the foundry by concentrating them in a separate room or, where this would be impracticable in an existing foundry, in an effectively partitioned off area in which no process other than dressing is carried on. A high standard of general ventilation should be maintained in all such rooms or places,

and all possible local dust suppression measures should also be applied to each process. These arrangements will help to prevent the spread of the dust to other parts of the foundry.

Dressing operations are sometimes done in the open air or in structures with open sides. In these circumstances, it is difficult both to control the dust effectively and to maintain a reasonable temperature and comfortable conditions, and it is therefore recommended that the operation should only be carried on in properly enclosed buildings.

Cleanliness and good housekeeping are discussed elsewhere in this report, but there are special features about dressing shops which should be stressed in this connection. Quantities of sand may accumulate on the floors and if they are to be kept as clean as they should be, the sand will have to be removed at frequent intervals. It is difficult to clean sand floors even when they are rammed hard, because the surface inevitably tends to become uneven. For dressing shops, therefore, prepared floors of concrete, brick, tarmacadam, wood, steel or iron plates, or other suitable material which can be cleaned effectively should always be provided. Well defined gangways should be provided in all dressing shops, and kept free from obstruction. Recommendations regarding floors and gangways are included in the sections of this report on cleanliness, good housekeeping and new foundries.

Recommendations

78. All dressing operations should be done inside buildings which have walls on all sides and a weatherproof roof.

79. Dressing operations should be concentrated either:

(*a*) in an area of the foundry set apart for the purpose, and be provided with effective and suitable local exhaust ventilation or other equally effective means of suppressing dust; or,

(*b*) in a separate room or in a separate space effectively partitioned off and should be, where practicable, provided with effective and suitable local exhaust ventilation or other effective means of suppressing dust.

80. In the last few years, research and development projects have resulted in the provision of local exhaust ventilation systems for most dressing tools and processes. These new methods should be absorbed within, and adapted to, the non-ferrous industry as quickly as possible.

81. Local exhaust ventilation applied to all dressing tools to control the dust at source is the ideal. Where complete control of dust is not practicable, the local exhaust ventilation should be supplemented by a high standard of general ventilation.

82. Dressing shops should be provided with prepared floors with hard and even surfaces which can be kept clean. Sand should not be used.

83. Gangways should be provided and kept free from obstruction.

VENTILATION

89. We have discussed the use of ventilating methods in various sections of this report, but we are including this section on the subject because it is greatly complicated in the industry by matters which may not normally come within the purview of a ventilating engineer. Ventilating equipment has been used, both to control temperature and to control dust and fume. In one section of this report

we have indicated certain experimental work which has been done on our behalf in an effort to control temperature by other means, and we have also described in many sections of this report some of the research and development projects which have been done on local exhaust ventilation. All this work will have a bearing on the amount of general ventilation that will be needed, and also on the optimum size of future foundry buildings. It is quite evident that we can make no specific recommendations at this stage, but we consider it a matter of importance that the industry should understand the lines along which we are thinking.

90. We reiterate that the best way of dealing with fumes and with high temperatures is to stop producing them. There is described in the section on the Thermal Environment, an experimental project which led to the design of a new furnace. This furnace, which is described in Appendix V, was used to melt aluminium for a pressure die-casting machine, and the investigators found that aluminium could be melted for this purpose, without the use of fluxes. It was also shown that the problem of radiant heat ceased to exist in the foundry in which the first eight of these furnaces were put to work. The building, which now houses these furnaces, is of generous proportions and is equipped with a copious general ventilating system. This was done because fumes and heat are more tolerable in a large building, and the lavish ventilating system was installed to remove both heat and fumes. The new melting units produce neither heat nor fumes and, in fact, the melting shop will now have to be heated during the winter. It would be much better if it were a smaller building, and the large amount of extraction ventilation equipment will not be used in the future. This is an example of the influence that furnace design and melting practice have on the need for ventilation.

We do not think that ventilation methods should be used to control the temperature of a foundry, because heat which makes a foundry uncomfortable is waste heat, and the fuel that supplied it was purchased to melt the metal and not to inconvenience the men. It may be necessary to use ventilation systems to remove convected heat until such time as furnace designs can be improved, but air movement will not remove radiant heat. Very large volumes of air will have to be moved to control convected heat, and as the air temperature rises, any ventilating system becomes less efficient as a means of removing heat, because the density of the air falls.

91. There will still be many cases where fumes and dust cannot be avoided and, in these cases, they will have to be controlled by ventilation methods. We are certain that, wherever it is possible, local exhaust ventilation should be applied at the point of origin of the dust or fume. We have noticed a definite tendency to allow fumes from ladles and furnaces to pollute foundry atmospheres in the hope that a general ventilation system would then remove them from the building; this is wrong, and all the fume which can be controlled at source should be so controlled before general ventilation methods are even considered. General ventilation can do no more than limit the concentration which might build up in a room. A good deal of work remains to be done on the design of local exhaust equipment to meet the various special requirements of the non-ferrous founding industry; so far as we know there has been no solution of the problem of collecting at source fumes from ladles in transit, although this represents in many foundries a major source of difficulty. Experimental work is in hand, and preliminary results have indicated one or two methods which might be susceptible of successful development; possibly the low volume high velocity system may be used[18].

Recommendation

84. Having summarised in this report a large amount of recent work on the subject, we recommend that the industry explore new methods of dust and fume suppression so that better foundry atmospheres may be obtained more efficiently.

ACCIDENT PREVENTION

Accident Analysis

92. Most of our report is devoted to the prevention of industrial disease in non-ferrous foundries, but the equally important problem of accident prevention in the industry has not been overlooked.

A classification of all the non-ferrous foundry accidents which have been reported to the Factory Department (*i.e.*, all accidents resulting in more than three days' incapacity) for the years 1953, 1954 and 1955 has been made and will be found in Appendix XVIII.

Principal Types of Accident

93. The tables show clearly that the accidents fall consistently into a relatively small number of groups, of which three are outstanding, namely

(*a*) Burns,

(*b*) Handling Material, and

(*c*) Falling Articles.

These three groups account for over 50 per cent. of the total accidents in non-ferrous foundries every year and many of these accidents result in three characteristic types of injury, viz.:

(i) Molten metal burns which include many foot and eye injuries.

(ii) Strains, hernias, etc.

(iii) Cuts, abrasions and bruises, again including many foot injuries.

Many of these accidents could be prevented by greater attention to some fairly simple precautions both by the managements and the employees as suggested in the following paragraphs.

Strains, etc.

It is clearly not practicable to mark the weight on every piece of equipment and on every job in the foundry; it is not practicable either to lay down standards of maximum weights because man is not a standardised machine and physical strength varies widely with different individuals.

We suggest for consideration the two following remedies:

(1) Education of the workers, especially the younger generation, in the correct methods of weight lifting, coupled with a warning to the older generation to recognise and respect the effects of increasing age.

(2) Increased application of mechanical handling.

Cuts and Abrasions (Sepsis)

94. This type of injury which frequently results from the handling of rough or irregular material with sharp points or edges could be greatly reduced by the more extensive provision and use of gloves or other forms of hand protection.

A high proportion of the injuries of this type subsequently turn septic and we strongly recommend that the necessity for immediate first-aid treatment should again be stressed both to managements and employees.

Burns

95. Burns from molten metal form a substantial proportion of the total and most of them occur during the handling of the metal. A very common cause is the spillage of metal due to the man who is carrying it tripping or stumbling over some irregularity or loose article in the floor, gangway or pouring aisle. Higher standards of tidiness and the proper maintenance of floors, etc. would do much to reduce this class of accident. A secondary or contributory factor in many of these accidents is the failure either to provide or wear suitable protective clothing and other protective equipment.

Eye Injuries

96. This type of injury, which is always potentially serious, occurs most frequently in the following processes:

(*a*) Grinding by abrasive wheels,

(*b*) Dressing and fettling with hand or portable tools,

(*c*) Handling of molten metal.

Many of these accidents could be prevented by the more extensive provision and use of goggles and screens.

There are certain statutory provisions requiring these preventative measures, but investigation has shown that there are at times special difficulties in handling molten metal; in addition workers, from mistaken motives, will sometimes refuse to wear goggles or face screens even when suitable types have been provided for them. Many cases arise, however, where the goggles provided are unsatisfactory, *e.g.*, they become misted through inadequate ventilation, thus obscuring the vision and creating a greater danger. Face screens, properly adjusted, afford good protection in some cases but they are not always satisfactory. We are therefore glad to note that you have set up a Joint Advisory Committee which includes members of the three foundry Joint Standing Committees to examine the whole question of suitable eye protection for persons at risk from molten metal.

We can see no valid reason why some form of eye protection should not be worn by men engaged in grinding, dressing or fettling. Several accidents have, however, occurred when a man engaged in one of these processes has temporarily removed his goggles for some quite legitimate purpose (*e.g.*, to clean them or to call a crane), and has been injured by a particle from another working position.

We are glad to note that you have already directed the attention of the whole foundry industry to this matter and have recommended that screens should be voluntarily provided wherever practicable (in addition to the wearing of goggles as required by law). A reminder as to the importance of this additional safeguard may not be out of place.

We appreciate the difficulties where the fettling of large castings is concerned, but it has already been shown in several cases that it is possible to introduce screens between adjacent working positions even with awkwardly shaped objects such as large marine propellers.

Foot Injuries

97. Many of these accidents arise through the dropping of articles in the course of handling or through the spillage of molten metal; in either case the wearing of suitable protective equipment would considerably reduce this type of accident and also reduce the severity of the injuries where they cannot be entirely prevented. Safety boots constitute the basis of any protective equipment for this type of injury and we are most anxious to see their use more widely adopted. We suggest that further prominence should be given to and further propaganda directed towards this very important subject.

98. *Other Causes of Accidents*

(1) *Power Driven Machinery*

The proportion of accidents caused by power driven machinery in non-ferrous foundries compares favourably with that in industry generally, but increasing mechanisation may introduce new dangers and it is most desirable that the question of safety should be considered at the design stage in any new plant and not tacked on as an afterthought when the plant has been produced. We therefore suggest that the attention of designers and suppliers of foundry plant and equipment should be directed to this recommendation.

(2) *Lighting*

It is impossible to estimate in how many cases inadequate lighting has been a contributory factor in the causation of accidents, but there can be no doubt that good lighting, both natural and artificial, will help towards their reduction; since good lighting shows up dust and dirt and acts therefore as an incentive to tidiness and cleanliness which have already been recommended.

Foundry Accident Prevention

99. We are convinced that some local organisation is desirable in every foundry. It is true that many firms already have committees, but much more can be done. It is not the function of this committee to go into the composition of Safety Committees but experience has shown that the best results are obtained where there exists a really keen interest in this work both on the part of the management and of the employees and it is a well established principle that both sides should be adequately represented.

Summary of Conclusions

100. The main points which have emerged from an examination of non-ferrous foundry accidents during the last three years are:

(1) The yearly totals remain substantially constant.

(2) The totals of the various causation groups are also relatively constant.

(3) Over 50 per cent. of the accidents each year are accounted for by three causation groups only, *i.e.*, Burns, Handling Materials and Falling Articles.

It is therefore clear that the yearly totals could be very considerably reduced by a concentrated and determined attack on these three groups, but, if a campaign of this nature is to be successful, two things are essential:

(1) There must be really keen interest and determination to succeed on the part of the management, and

(2) this must be supported by equally keen interest and the fullest co-operation on the part of the employees.

The lines of action which would appear to be most promising in the reduction of these accidents are as follows:—

(1) A much higher standard of housekeeping, especially as regards the provision and maintenance of better floors, gangways and pouring aisles, with particular attention to the elimination of obstructions on such floors and gangways.

(2) The wider provision of suitable protective clothing and other protective devices.

(3) The proper care and use of such protective equipment by the workmen.

(4) Early and correct first-aid treatment.

(5) Better training in safety principles and instructions in safe methods and practices with particular attention to weight lifting.

(6) The setting up of some domestic organisation or arrangements in every foundry whereby accident prevention measures can be discussed and dealt with jointly by management and employees.

NEW FOUNDRIES

101. We think it is a matter of great importance that the mistakes of the past should not be repeated; many existing foundries suffer from the old buildings in which they are housed. These buildings are often essentially unsuitable, and great difficulty may be experienced in providing good working conditions simply because of the fundamental defects in the premises. We have discussed very carefully the possibility of making specific recommendations for new foundries, but it is too early for us to recommend with certainty, and so we have decided to defer this matter until we have acquired further information.

We have, however, discussed the subject of gangways and we agree with the recommendations of the Garrett Report which we think should be used as a guide in non-ferrous foundries. Good unobstructed gangways and pouring aisles are necessary in foundries and in new ones their widths should not be less than those suggested in the recommendations at the end of this section.

It is evident that new foundries should be built in such a fashion that compliance with the recommendations contained in this report becomes practicable. Where we have made recommendations, this is possible, and we think it should be done. On the other hand, there are major considerations in this report on which we have reached no conclusions, and we say this so as not to mislead the industry.

102. An outstanding example of this arises from the development of the reverberatory furnace for melting aluminium which is referred to in the sections entitled Thermal Environment and Ventilation and fully described in Appendices IV and V.

The heat and fumes which were formerly dissipated in the workrooms by the old bale-out furnaces necessitated high buildings with copious ventilation, but since the new furnace has almost eliminated these fumes and heat it appears that such high buildings will no longer be necessary and the ventilation can be greatly reduced. In fact, the main problem now appears to be the provision of sufficient heat to maintain a reasonable temperature in winter.

The implications from this work are, of course, that the most suitable kind of building for a non-ferrous foundry may be quite different from anything that

has been envisaged in the past. It is, however, impossible to make any general recommendations on the results achieved in one case. Our Technical Sub-Committee is proceeding with the necessary research and development work.

Recommendations

85. Good unobstructed gangways and pouring aisles should be provided, of the following widths:

Gangways

(I) If not used for carrying molten metal—at least 3 ft. wide.

(II) If used for carrying molten metal—

(*a*) where truck ladles are used exclusively—at least 24 in. wider than the over-all width of the ladle ;

(*b*) where hand shanks are carried by not more than two men—at least 3 ft. wide;

(*c*) where hand shanks are carried by more than two men—at least 4 ft. wide;

(*d*) where used for simultaneous travel in both directions by men carrying hand shanks—at least 6 ft. wide.

Pouring Aisles

(III) Aisles where molten metal is carried in hand or bull ladles and poured into moulds on moulding floors by not more than two men per ladle—at least 18 in. wide, except where moulds alongside the aisle are more than 20 in. high above the aisle level, in which case the aisle should be not less than 24 in. wide. All measurements should be taken between the extreme ends of the box handles or other projections.

(IV) Where molten metal is carried in hand or bull ladles and poured by more than two men per ladle—at least 30 in. wide.

(V) Where crane, trolley or truck ladles are used—sufficiently wide to do the work safely.

86. Where overhead cranes controlled from the floor are used, a clear gangway should be provided for the operator when the crane is handling hot metal.

CONCLUDING REMARKS

103. Our work is by no means completed, but we thought that we should indicate to you the progress that we have made, and we hope that you will see your way to publish this report so that the industry may also see both the stage reached and the direction in which we are moving. We have covered many general matters in the early sections of this report, which were based on the Garrett Report, and we have also included a general summary of much of the work that has been done since that Report. We have selected those matters which we think will be of interest to non-ferrous founders, and even at the risk of some repetition we have included, in this report, work which has been published elsewhere so that the non-ferrous trade might have a convenient reference book which would cover the whole subject. We have also included a full bibliography through which all the original work that has been done on

conditions in foundries in recent years can be traced. Finally, we have, of course, included the research and development work that has been done for us. This work is still in progress.

104. One further general comment we make because we think it is a matter of great importance. We are certain that the achievement of good working conditions within the industry will demand the fullest co-operation from all who work in it. Foundrymen, technical men and scientists, employers and Trade Union members can all usefully contribute. There are legal obligations on both employers and employees, but we look for a sense of responsibility which will lead both of them to devise and to use every possible means by which the standard of the industry can be raised.

105. *Acknowledgements*

We desire to express our grateful thanks to Renfrew Foundries Ltd. for their valuable help in the development of the reverberatory furnace for melting aluminium and also in making this development available to the whole industry. We are also greatly indebted to Dr. D. Turner of the Medical Research Council for his most valuable help in this work.

Our thanks are also due to the British Cast Iron Research Association and the British Steel Castings Research Association for permission to reproduce certain technical papers and also to many other technical organisations, private firms and individuals whom we have consulted from time to time.

We acknowledge the services of Mr. W. A. Attwood who has acted as the Secretary to the Committee and thank him for the valuable work done by him.

We have the honour to be, Sir,

Your obedient Servants,

(*signed*) R. BRAMLEY-HARKER (*Chairman*)
T. W. MCCULLOUGH (*ex-Chairman*)
J. H. BARWELL
J. M. BOYD
F. G. BURRELL
G. W. CHILTON
A. EYDEN
J. GARDNER
A. GRAHAM
L. W. GUMMER
P. B. HIGGINS
W. T. HOBKIRK
G. T. HYSLOP
P. R. KEALEY
W. B. LAWRIE
GAVIN MARTIN
C. E. WATSON
J. H. WIGGLESWORTH
F. W. WINSLADE
W. A. ATTWOOD (*Secretary*)

APPENDICES

Appendix I

RECOMMENDATIONS FROM REPORT ON THE DRYING OF MOULDS BY PORTABLE DRYERS

1. No ordinary open fire should be used for mould drying other than in exceptional cases where it can be shown to be unavoidable.

2. Hard cupola coke is the most suitable fuel, whilst hard furnace coke is also suitable. Gas coke is less satisfactory.

3. The coke should be graded and the size should not be less than $1\frac{1}{2}$ in. The size range from 2 in. to 3 in., when free from fines, gives the best results.

4. Gas coke in the size range less than 1 in. is definitely unsuitable and should not be used.

5. Manufacturers of mould dryers should ensure that the depth of the fuel bed is not such as to produce excessive carbon monoxide in the products of combustion.

6. Coke should be charged frequently and in small quantities, or alternatively a controlled feeding device should be employed.

7. Manufacturers should ensure that the fan will overcome the resistance of the dryer and the mould.

8. The fan should supply a sufficient volume of air to the dryer.

9. Valves should be simple in operation.

10. Valves should be designed so that they remain operative in spite of dirt and rough handling.

11. Where separate valves control the primary and secondary air it should not be possible to shut off the secondary air completely.

12. The grate should be designed to allow of easy clinkering and cleaning.

13. The grate of the dryer should be kept clean and clinker or ash should not be allowed to accumulate on it.

14. Mould dryers should be used in such a fashion that there is as little restriction as possible between the dryer outlet and the mould outlet.

15. The end of the main discharge pipe from the dryer should be not less than $1\frac{1}{2}$ times the pipe diameter from the nearest protection plate or mould surface.

16. The total area of the discharge openings from the mould should be not less than $1\frac{1}{2}$ times the area of the dryer discharge pipe. If this cannot be ensured by the use of the runners and risers, or by wedging up the cope, then a "lift out" piece should be provided to give the required area.

17. The cross-sectional area of any ducting between the dryer and the mould should be not less than the cross-sectional area of the dryer outlet.

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18. If hends are included in any ducting between dryer and mould, they should be of the full duct diameter and round rather than ahrupt; it should not be forgotten that a right-angle hend reduces the effective cross-sectional area of the pipe to seven-tenths its original area, so that pipe diameters should be correspondingly increased as the angle between the arms of the bend decreases.

19. A CO/CO_2 ratio of not more than 0·05 should he ohtained within five minutes of recharging the dryer with cold coke.

20. A CO/CO_2 ratio of not more than 0·02 should he obtained within ten minutes of recharging the dryer with cold coke.

21. These ratios should be ohtained when the dryer is working at the makers' stated rate, and discharging against a back pressure of 1 in. water gauge in the discharge pipe.

22. Low sulphur coke should he used to minimise the production of sulphur dioxide.

23. When controlling the temperature of the exit gases hy adjusting the valves, the combustion rate should be high enough to maintain a hrightly incandescent fuel hed.

24. The mechanical design should he simple so that even after much use or neglect, the dryer will function correctly.

25. The dryer should be designed so that it can he lifted in safety.

26. Initial lighting of the dryer should be safe and simple.

27. Wherever possible an initial charge of hrightly hurning coke should he used to avoid smoke, and the fuel hed should he huilt up gradually to the recommended height.

28. Wide fluctuations in the proportions of fuel and air should be avoided.

29. Mould dryers should not he used in confined, unventilated spaces.

30. When the discharging gases from a mould escape through a single opening it is probably worth while fitting a short pipe to the opening so that the gas discharge will be ahove hreathing level.

31. Manufacturers should issue clear and simple instructions on the use of dryers and these instructions should he readily availahle to operators. This might he achieved by affixing instruction plates to all dryers. Strict compliance should be maintained with the makers' instructions when using dryers.

Appendix II

RECOMMENDATIONS FROM TECHNICAL REPORT ON PRACTICAL METHODS OF REDUCING THE AMOUNT OF FUMES FROM OIL BONDED CORES

General

1. Attention should always be given to the technical control of operations in all core shops.

2. The importance of the mixing operations should not be underestimated.

3. A high standard of good housekeeping should be maintained in the core shop and in the core sand mixing plant.

4. The number of mixtures used should be reduced to a minimum.

5. All operators should be provided with full and clear instructions.

6. The extravagant use of binders should be avoided.

7. The core binder suppliers should be consulted in the choice and use of binders.

Storage of Core Binders

8. Proper storage should be provided for binders and, in particular, extremes of temperature should be avoided; also in the case of powders dampness should be avoided. Old stocks should be used first.

Sand

9. Careful consideration should always be given to the grade of sand to be used, which should be selected with regard to the properties which will be required of it.

10. The proportion of clay and other fines should be restricted to the minimum needed for the work.

Sand Temperature

11. Sand should be cooled before mixing.

Mixing

12. All mixtures should be made on the basis of weight.

13. Semi-solid additions should be weighed.

14. Full details of each mixture should be determined.

15. Strict control should be exercised to ensure that there is no deviation from the specified mixture.

Storage of Mixed Sand

16. Proper storage should be provided for mixed core sand to ensure conditions which reduce to the lowest possible level the rate of evaporation of the moisture.

Baking

17. Cores should not be used in an underbaked condition.

18. The most satisfactory baking cycle should be ascertained and subsequently followed rigidly.

19. So far as is possible cores of a similar size sbould be baked together.

20. Every effort should be made to avoid the constant opening and shutting of batch stove doors.

21. Fuming cores sbould be cooled either in the cooling cbamber of tbe stove or under a hood provided with efficient exhaust ventilation.

22. Efficient stoves provided with means for recording and controlling temperature should be used.

23. Stoves should not be beated by an ordinary open fire.

24. Adequate and suitable flue systems sbould be fitted to all stoves to ensure that the fumes from the stoves do not enter the foundry or core sbop.

Casting

25. All vents sbould be lighted after casting.

Types of Cores

26. "Shell" cores sbould be used wherever possible to replace large solid cores.

Core Block Moulding

27. The minimum possible quantity of binder should be used.

28. Moulds should be cast under a hood fitted with efficient local exhaust ventilation.

Appendix III

THE CONTROL OF FUMES FROM THE FLUXING AND CASTING OF MAGNESIUM (LOW VOLUME HIGH VELOCITY VENTILATING SYSTEM)

1. The fluxing and de-gassing of certain non-ferrous metals gives rise to large quantities of fume, which appear at different stages in the process. It is not always easy to control this fume, and the difficulties attendant upon the application of local exhaust ventilation systems may depend upon the particular part of the process from which the fume arises. Many alloys are fluxed in a crucible which remains, throughout the process, in the lift-out furnace or the bale-out furnace, in which the alloy was melted. In these circumstances, it is normal practice to apply local exhaust ventilation through a hood which is placed vertically above the furnace. These hoods are not always particularly efficient, because a large amount of fume rising at high velocity will often, after striking the hood, billow out and leak away into the general atmosphere of the foundry. Even if the hood is efficient, it suffers from the great disadvantage that it does nothing to protect the men who are working at the crucible, if they stand in such a position as to be under the hood itself. When this occurs, the whole of the fume from the process is taken through the breathing zone of the men before it is extracted. On the other hand, a hood of this type will remove the fume from the foundry and so will serve to protect other workers in the building. The hot rising fumes will heat the hood and the ducting to which it is connected, and so provide an overhead source of radiant heat, which may mean considerable discomfort to the men working below it. This is obviously undesirable. Finally, overhead hoods and ducting cannot easily be installed in foundries where cranes are needed. For this reason, side hoods have been installed in certain cases, and they have very definite advantages if the general foundry layout provides sufficient floor space in which to instal them. If they are efficient, and if they are so placed that the operator never works between the source of dust and the hood face, side hoods will ensure that the fume is extracted without being taken through the breathing zone of any person in the room in which they are installed. Crucibles are sometimes taken out of the furnace, in which the metal was melted, before the flux addition is made. In this case, the crucible normally stands on the foundry floor and local exhaust ventilation can be provided, either by means of an overhead hood, or by means of a side hood.

Very considerable quantities of fume may also be evolved from the stream of metal after it has been fluxed, and as it flows from a tilting furnace into a ladle. The control of this fume is generally fairly difficult, particularly if the ladle is so large that it must be suspended from an overhead crane. Quite clearly, the furnace itself will move out as it tilts and so may well leave the zone of influence of an overhead hood. Any extension, which could perhaps be fitted to such an overhead hood, would often be fouled by the ladle or the crane ropes, and so may not be feasible. It is common

practice, therefore, to rely on general ventilation to control the fumes which arise from this part of the process. When these ladles have been filled, they have to be carried either by hand or in a crane to the pouring position, and if the metal is still fuming this offers a difficult problem in local exhaust ventilation which has not yet been satisfactorily solved. Further fumes may be evolved when the metal is being cast, and here again, there is some difficulty in providing suitable and adequate local exhaust ventilation. It is normal, in these two latter cases, to rely on general ventilation to clear the air of the foundry as quickly as possible although, for obvious reasons, this is not altogether satisfactory. Finally, some metals continue to fume after they have been cast. If the work is cast on a conveyor belt, this fume can be dealt with by passing the belt through a ventilated tunnel, but if the moulds are cast all over the foundry floor, general ventilation is the only method that has been used up to the present.

2. A new method of local exhaust ventilation which was described[15, 16] in 1954, by a member of our Committee, Mr. W. B. Lawrie and two members of an industrial organisation, Mr. A. T. Holman and Mr. E. B. James, may offer some solution to these problems. This new system, which represents a change in the fundamental conceptions of local exhaust ventilation, uses very low volumes of air moving at very high velocity. It has come to be known, therefore, as the low volume high velocity system. It was first used to control the dust produced by rock drills. In this application, the dust is extracted through a hollow drill steel, and through the rock drill itself, in a ventilating air stream moving at a velocity of 16,000 to 18,000 ft. per minute. This very high velocity is attained, in the case of a rock drill, from an annular air ejector, which is normally designed to generate a static vacuum of 13 to 15 in. of mercury and which, therefore, gives a running vacuum of about 10 in. of mercury. A large amount of research and development work has been completed since 1954, and the system has now been applied to a wide range of foundry tools and processes[16, 17, 18, 19, 20]. It works at much higher vacua than has been normal in the past, and the very small air volumes, which may be as low as 6½ cu. ft. of free air per minute in certain cases, allow of the use of small diameter ducts. In fact, the largest diameter duct that has been used on any application has been a 2½ in. diameter flexible hose, and much of the work has been done on polythene hose with a diameter of ⅝ in. These ducts are small enough to be applied very close to the point of origin of the dust or fume, so that it can be controlled at source. The air velocity at the duct inlet is not normally less than 6,000 ft. per minute, and may be increased to as much as 18,000 ft. per minute without difficulty. This velocity is great enough, therefore, to control fumes which are themselves being

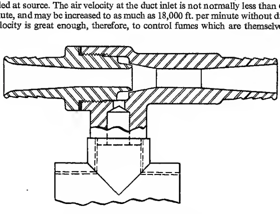

Figure 1. Cross Section of Eductor.

Illustration by courtesy of the Institution of Mechanical Engineers

evolved at high velocity. Conventional exhaust hoods may have to be fitted at some distance from the source of the fume, because the ventilating air moves at low velocity and so would not control a high velocity cloud of fume until it had decelerated. This difficulty has been overcome by the new ventilating system.

For reasons of convenience, the early experimental work was all done on Eductors. These Eductors are annular air ejectors, which operate from compressed air lines at 80 lbs. per square inch pressure, and the general design can be seen from figure 1. The ejectors are normally used in mining practice at a static vacuum of 13 to 15 in. of mercury, which gives a running vacuum of 10 in. of mercury. Thus, for the purposes of the work on foundry machines and processes, the ejectors have been modified as occasion has demanded. In the case of pneumatic chisels, where a very low volume was needed, the ejector was designed to give a static vacuum as high as 18 to 20 in. of mercury, while fumes have been controlled by the suction induced from ejectors with a running vacuum as low as 1 in. of mercury. The ejectors need not be used as a source of vacuum, because all the systems can be exhausted, either by fans or by rotary exhausters. Quite clearly, the local conditions of any particular installation will determine the most suitable source of vacuum.

3. The application of fluxes to molten magnesium produces a hot column of dense fume, which rises rapidly past the face of the operator to give conditions which can be seen in Plate 4. This fume[18] was controlled by the new low volume high velocity system through the circular duct which can be seen on the top of the crucible in Plate 5. The inlet ports on the inside surface of the ring were adjusted in size, and so spaced that there was an average intake velocity round the ring of 6,000 to 7,000 ft. per minute. The fume control, which resulted from the use of this ring, can be seen by comparing Plate 4 with Plate 5. The slight leakage at the left-hand side of Plate 5 was due to the fact that the experimental ring did not quite fit the crucible top.

The extraction air was provided by two compressed air ejectors which together extracted about 160 cu. ft. of free air per minute at a running vacuum of just over 1 in. of mercury. The experimental work was done on a crucible which had been placed on the foundry floor after having been taken from the lift-out furnace in which the metal was melted.

4. Magnesium still continues to fume, both when it is being cast and after the metal has been poured. In an attempt to control the fume at this stage of the process, a small circular duct, 7 in. in diameter, was placed round the runner bush of the box during casting. Air was extracted from the ports on the inner surface of this ring which can be seen in Plate 6. A compressed air ejector was again used to induce about 70 cu. ft. of free air per minute at a running vacuum of just over 1 in. of mercury.

Plate 6 shows the conditions immediately after pouring, when the exhaust system was not in use, while Plate 7 is a comparable picture with the exhaust operating. It is of interest to notice that the small exhaust ring controls the fumes rising from a vent in the middle of the box as well as controlling the fume from the runner bush itself.

These experiments represent early work, in which it has been shown that the low volume high velocity system can be used to control fumes from magnesium in certain cases. The source of vacuum in most cases was a compressed air ejector, but there is no reason why rotary exhausters should not be used, or fans if these are more convenient.

APPENDIX IV

THE THERMAL ENVIRONMENT

1. It is a well-known fact that conditions in non-ferrous foundries may become very hot and unpleasant, particularly in summer. In consequence, an effort has been made both to determine the thermal environment and to control it. The work was undertaken by two members of our Committee, Mr. A. Eyden and Mr. W. B. Lawrie, in conjunction with Dr. D. Turner of the Medical Research Council and Mr. A. Edwards, who is the Chief Engineer of an industrial firm. This work, which has recently been published[21], began with a survey of conditions in 14 foundries, which were chosen to present a good cross-section of the industry. It was evident from the outset that this survey could only be a preliminary one, and that when it had been completed, it would be, by no means, a full statement of the position in the industry. Obviously the wide range of metals and alloys that are melted and the great diversity of melting methods precluded anything like a complete examination of the industry within the time available.

The early investigations were undertaken during the summer of 1954, when the weather was never really hot. This means that the worst conditions that might appear were never measured, but it is not a matter of much importance so long as this is understood, because it merely means that the survey provided conditions which will be met throughout the industry in many days during the year. It was clear that, in certain cases, conditions approached, if they did not exceed, the limits of endurance, and this was confirmed by the fact that some plants close down about midday in hot summer weather. There was little information available at the outset when it was thought that the main cause of the trouble was the radiant heat from furnaces. For this reason, the experiments were arranged to investigate this point in particular, but later in the work it became evident that radiation might not be so predominant a factor as had been supposed.

The original work was, of course, purely thermal. On the other hand, the foundry environment is affected by so many factors that no full account of the matter can be given by thermal investigations alone. It is quite obvious that the furnaces themselves represent the heat source in the foundry. It is also clear, however, that the environmental conditions will be greatly affected by the amount of general ventilation in the building. This, in turn, might well have been determined by the need to remove large volumes of fume generated by the fluxing of certain alloys. The ventilating air which is extracted will not, of course, remove radiant heat, but it will reduce the amount of convected heat that remains in the building, and so will have its effect on the ultimate thermal environment. The need for fluxing is perhaps a metallurgical matter, but there can be no doubt that it is also affected by such considerations as the design of the runner system to the dies. If, therefore, a runner system can be improved, so that an alloy can be cast at a different temperature and perhaps require, as a result, less fluxing, it may be possible to reduce the amount of ventilation that is needed for the building. This, in turn, will reduce the amount of convected heat which is removed by the outgoing air, and so may well make thermal conditions worse. Such a sequence of

events would mean that an alteration in runner design had reduced the ventilation requirements, improved the conditions so far as fumes were concerned, and made the thermal environment more severe. This kind of thing does happen in non-ferrous foundries, and it is a matter of great importance when trying to control the thermal environment, that other matters, which at first sight may seem quite irrelevant, are not forgotten. Many matters of this kind were discussed during the original investigations, and a good deal of information was acquired which has not yet been used. Finally, for a variety of reasons, the investigators concentrated on the measurement and control of radiant heat from bale-out furnaces.

2. The measurements were made only in those positions at which men were exposed to warm conditions for considerable parts of each day's work. This was done because the apparatus available did not allow the investigators to make any reliable assessment of short exposures to very hot conditions. In each position air temperature, air speed, humidity and intensity of radiation were measured. The air temperature was measured with a mercury in glass thermometer, which was shielded from the effects of radiation. The air speed was measured with a silvered katathermometer, and the humidity was measured with a sling hygrometer. The radiation intensity was measured with a thermopile, which was mounted on a tripod at a height of 4 ft. 6 in. in such a fashion that the radiation incident from any direction could be measured. In each position a total of 76 readings of intensity was taken, so that the incident radiation from the entire sphere surrounding the point of observation was measured. These results enabled "radiation contour" lines to be drawn to indicate the location of the high temperature sources in any plane; they also enabled the mean radiant temperature to be calculated from the average of the 76 readings. The globe thermometer was not used for many readings, because the local sources of radiant heat were too extreme for this instrument to give a reliable indication of the mean radiant temperature.

3. The environmental requirements of man are briefly discussed in the published paper[31], and fully discussed by Bedford[43] and Haines and Hatch[44]. Men should not be required to work regularly and for long periods in a thermal environment which imposes severe loads on the temperature regulatory mechanisms of the body. In a hot environment, it may be difficult for the body to lose to the surroundings the heat produced by muscular activity, and this leads to an increase in the body temperature which results in fatigue and possibly in collapse.

Heat may be exchanged between a man's body and his surroundings by the evaporation of sweat, or by convection or by radiation. If the surroundings are hotter than the man's body, the heat exchange which occurs by convection and by radiation will result in heat passing from the surroundings to the man, so that his body will be heated. If these conditions occur in a foundry, they mean that the only method by which the man can lose heat is by the evaporation of sweat.

Convective heat transfer from one object to another results from the movement of the air surrounding the two objects when the heat is carried by the air from the warmer object to the cooler one. Convective heat may, therefore, be removed by ventilation because if the heated air is extracted before it comes into contact with the cooler object, that object will not be warmed. This is one reason, therefore, why men feel cooler in foundries in which copious exhaust and general ventilation systems are installed. It is, however, an expensive method of removing heat and it may give further trouble by reason of draughts or because of the difficulty of warming the building during the colder months in the winter.

Radiant heat passes directly from one body to another, and is not affected by any change in the temperature or the movement of the intermediate air. Radiant heat cannot therefore be removed by a ventilating system, although men can be shielded against radiation by the use of suitable screens.

4. Many of the results which were obtained during the thermal survey are given in the published paper[31] where it is also indicated that a good deal more work remains to be done on many aspects of the problem. The temperature measurements were made

on gas and oil fired bale-out furnaces, oil fired rotary furnaces, oil and coke fired lift out furnaces, an oil fired regenerative furnace, an oil fired reverberatory furnace and low frequency, high frequency and direct arc electric furnaces. The range of metals covered included aluminium alloys, gun-metal, magnesium, bronzes and brass, and the processes that were investigated included ingot casting, sand casting on the foundry floor and on conveyor belts, gravity die casting, pressure die casting and centrifugal casting. The earlier work was purely exploratory, and was intended to provide a factual basis from which the workers might be able to determine those points at which remedial measures could be most easily and most profitably applied. The preliminary examination did, in fact, suffice for the purpose for which it was designed, and much of the later work was concentrated on bale-out furnaces in die-casting foundries, and most of the discussion in the original paper concerns this particular non-ferrous process. It was found that air temperature and radiation are both important factors in the overheating of the foundries. At this stage of the work, the investigators were led to the following conclusions :—

"(1) The thermal environment has been surveyed in 14 non-ferrous foundries, selected to give a good cross-section of the industry.

(2) It has been shown that, in certain cases, conditions approach, if they do not exceed, the limits of endurance. These measurements were confirmed by the fact that some units close about midday in hot summer weather.

(3) Electric furnaces produce less radiant heat than others.

(4) Furnace body insulation was generally poor, although one oil fired furnace was no more than hand warm and the electric furnaces were good in this respect.

(5) Gravity dies emitted a considerable amount of radiant heat.

(6) Pressure die-casting machines do not give off much radiation.

(7) The thermal environment in the proximity of melting furnaces can be improved either by controlling convection or by eliminating radiation.

(8) The control of convection involves the use of lavish local exhaust ventilation systems. This method is expensive in itself, it leads to more expense in heating the building in winter, and it quite simply represents the use of power to remove heat, which has been wasted by the furnace.

(9) Exhaust canopies often increase the overhead radiation considerably.

(10) The elimination of radiation implies that the fuel is being used to melt the metal, and not wasted to make the men uncomfortable. It is therefore cheaper and more efficient than other methods of heat control.

(11) The complexity of the problem and the diversity of the industry demands that each problem be dealt with separately. In consequence, later work was restricted to oil fired bale-out furnaces melting aluminium for pressure die-casting.

(12) Large amounts of radiant heat come from the bale-out furnace body, the surface of the molten metal and the flame projecting from the flue pipe. The body insulation should be improved, and the molten metal should be covered with a sliding lid. In one case, where such a lid was provided, there was stated to be a 20 per cent. improvement in fuel efficiency. The flame projecting from the flue made the bale-out furnace singularly inefficient."

Appendix V

A REVERBERATORY MELTING FURNACE

1. The thermal work, which has already been described in Appendix IV, led the investigators to the conclusion that large amounts of radiant heat came from bale-out furnaces, and that working conditions were often not very good when this type of furnace was in use. Heavy radiation losses, of course, implied an inefficient melting unit in which heat which had been purchased to melt the metal was in fact used to make the men uncomfortable. It was realised that conditions could be alleviated for the men by the provision of suitable screens, which would protect them from this radiant heat, or by the installation of copious ventilation systems, which would remove the convective heat. It was decided, however, that it would be far better to try to attain more efficient melting when there would be less radiation loss and, in consequence, better conditions with lower fuel costs[31].

2. Before experimental work was commenced on new furnace designs, the fuel efficiency was estimated on one bale-out furnace. The furnace was used to melt 250 lb. of aluminium for use in a pressure die-casting machine, and although there was insufficient time to construct careful thermal balance sheets, a quick check showed that the fuel efficiency was of the order of 13·55 per cent. This efficiency was estimated on a crucible which was only two or three days old, because it was known that the rate of heat transfer through the crucible falls as the crucible is used. An old crucible might have been expected, therefore, to show a still lower thermal efficiency. The combination of low fuel efficiency and hot working conditions led, therefore, to the design of a new reverberatory furnace. The first furnace that was built was designed to melt 250 lb. of metal and to serve the same pressure die machine and melt the same aluminium alloy that had been used in the previous work, and the new furnace replaced the bale-out furnace on which the fuel efficiency had been estimated. It was found that the first prototype of the reverberatory furnace design gave a fuel efficiency of 28·65 per cent., and it is a point of some interest to note that this one reverberatory furnace replaced two bale-out furnaces, both the melting furnace and the holding furnace, and finally gave slightly more metal than the pressure die machine could take.

These results encouraged the investigators to proceed with a second prototype furnace which is sketched in Figure 2. The furnace is described in the original paper[31], but it melted 620 lb. of aluminium to a temperature of 600°C., and showed a fuel efficiency of 31·9 per cent. The thermal environment resulting from the use of this furnace is also described in the original paper[31], where it is shown that the mean radiant temperature was down to 88°F. which was the lowest recorded in any foundry of this type throughout the work.

3. The use of a reverberatory furnace, in which the flame plays directly onto the metal, led at once to questions of fluxing and de-gassing. It is quite impossible to discuss this matter in general, because it must obviously be examined in the particular circumstances of every alloy being melted. It was, however, found that with the new reverberatory furnace melting one particular aluminium alloy for a pressure die-casting machine,

good castings, could be made without fluxing and without de-gassing. Efforts were also made to estimate the amount of metal lost during melting, and a series of tests gave an average of 0·81 per cent. for the melting loss.

4. The installation of a number of these new reverberatory furnaces in one foundry resulted in great changes in the ventilation requirements of the building. In the first place, the absence of fumes by reason of the abolition of processes of fluxing and de-gassing meant that much of the ventilation system could at once be stopped. At the same time, there was no necessity to remove air for the purpose of heat control, and indeed the furnaces were found to be so cool in practice that, after the ventilating system had been shut off, the main requisite in winter was a heating system to bring the foundry to a reasonable temperature.

5. The results of all this work led the authors of the original paper to the following conclusions :—

"(1) Fuel efficiency in one bale-out furnace was only 13·55 per cent.

(2) A reverberatory furnace, which replaced two bale-out furnaces, was designed and gave a fuel efficiency of 31·9 per cent.

(3) Satisfactory aluminium pressure die castings were made in this reverberatory furnace without either fluxing or de-gassing.

(4) The whole question of fluxing and de-gassing requires much more attention.

(5) Foundry ventilation affects the thermal environment. Efficient furnace design and little or no fluxing and de-gassing would reduce ventilation requirements. Much work remains to be done, but the recent developments in low volume high velocity ventilation may well be of use in non-ferrous foundries."

APPENDIX VI

REQUIREMENTS FOR EFFICIENT DUST SUPPRESSION AT FOUNDRY KNOCK-OUTS

THE BRITISH CAST IRON RESEARCH ASSOCIATION

Foundry Ventilation and Dust Control

B.C.I.R.A. Conference, Harrogate, 27th–29th April, 1955

Presented on behalf of the B.C.I.R.A. Foundry Atmospheres Committee

By A. W. EVANS* and O. H. JACOBSEN†

"This survey of methods of exhausting dust during knock-out operations was originally presented on behalf of the B.C.I.R.A. Foundry Atmospheres Committee by two of its members at a B.C.I.R.A. Conference on Foundry Ventilation and Dust Control at Harrogate in April 1955[33]. It is reprinted from the Proceedings of this Conference."

Introduction

The design of satisfactory exhaust at knock-outs depends on a variety of factors, mainly comprising:

(1) The size and type of casting and mould box.

(2) The nature of the moulding sand and its moisture content.

(3) The method of handling both the boxes and the castings.

(4) The location of the knock-out in relation to the foundry building with its access doorways, windows, etc., and prevailing cross draughts.

In view of the variety of factors governing the exhaust hood form, it is impossible to lay down a basis of standard design. Each installation must be considered on its merits, and should be the responsibility of engineers with special experience in this class of work.

With mechanisation it is necessary in most cases for air exhaust to be applied not only to the knock-out, but also to the remainder of the sand handling system, as required to prevent contamination of the general atmosphere of the foundry from these other sources.

The importance of keeping up the moisture level of all sand on floors, in transit, or subject to vibration cannot be over-emphasized. If the moisture content of the sand is not allowed to fall below about one-half of that normally required for moulding, no dust will be produced by any foundry operation.

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Fundamentals of Hood Design

1. To prevent dust from entering the worker's breathing zone, so that although a dust cloud may exist, they will breath wholesome air.
2. The point of exhaust to be as close as possible to the source of dust.
3. Enclosure round source to be as complete as possible. In order to achieve the maximum efficiency at minimum cost, the design of hood must take all the foregoing factors into account. Air outlets can be controlled by mechanical means such as a baffle plate, louvres, etc., but an intake pipe cannot be so controlled. The crudest form of intake, an open-ended pipe, will draw air in from all round, even from behind, but by the addition of the backplate, the inward flow of air is concentrated to the front. (Figures 3a and 3b).

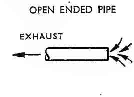

Figure 3a

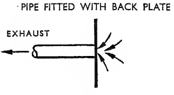

Figure 3b

In designing an efficient hood, the contour of the backplate is of vital importance, as a good design will achieve efficient results with a minimum rate of air extraction. With a bad profile an appreciable increase in the volume of air extracted will be necessary to achieve the same result.

Most knock-outs deal with hot sand, and cause the dust and fume-laden air to rise above the knock-out with appreciable speed. The best extraction efficiency is obtained when this natural flow is used to assist the action of the hood. (Figure 4).

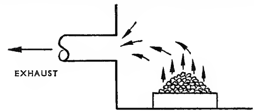

Figure 4

The primary purpose of the hood is to prevent the fine dust and fume from reaching the breathing zone of the workers in the area and to prevent it from spreading into the remainder of the foundry building. The layout of equipment in a foundry should, therefore, be planned so that adequate space is available for an efficient exhaust hood.

When planning new installations, consideration should always be given to locating the knock-out in a separate building or individual enclosure within the main building, in order to simplify the design of the exhaust plant.

In the case of existing installations, the casting handling system adjacent to the knock-out may be such that an efficient hood is precluded. In such a case it may be necessary to alter the handling methods so as to allow the accommodation of an efficient hood.

The proper location of the hood is of first importance, and the method of handling mould boxes, returned empties and castings should, therefore, be planned initially in conjunction with the ventilating Engineer.

Methods of Exhausting

(1) Fully enclosed knock-out.

(2) Side draught.

(3) Down draught.

(4) Up draught.

(5) General ventilation.

1. *Fully enclosed Knock-out.* The fully enclosed system is the ideal method of dust and fume control, as the knock-out is provided with a complete enclosure, with openings on the inlet side for the entry of the moulds, and on the discharge side for the removal of castings and mould boxes. The relatively small area of the openings enables adequate exhaust to be provided with appreciably less air volume than for the other systems described and it is, therefore, considerably cheaper. As in the case of the side draught hood, there is no interference by the exhaust air with the constitution of the moulding sand, and the system is largely protected from the harmful effects of cross draughts in the building. It would appear that this system can be applied on fully mechanised plants, employing standard mould boxes, and on snap flask work. In the past, however, despite its substantial advantages, the system has only been adopted to a limited extent, possibly because difficulties would be encountered in modifying existing plants. The system should be developed in future mechanised plants, but complete enclosure of the knock-out is both mechanically difficult and expensive compared with the other methods of dust and fume control.

2. *Side Draught.* Side draught is effected by means of a hood mounted above floor level and immediately alongside the knock-out point with suction pipe connected to the hood.

The size and position of the suction opening must be governed by individual circumstances, as explained earlier. The suction opening should be mounted in a screen above the level of the top of the mould box, and on the side of the knock-out remote from the operator's working position. In this way the rising dust is drawn to one side of the grid and away from the operators. The top of the hood should be arranged to overhang the knock-out as far as is practicable. The hood should be located close to the edge of the long side of the knock-out and it is not sufficient for the vertical screen to terminate at a height of 2 ft. or 3 ft. above the box. If the knock-out is exposed to cross draughts, the area should be isolated by means of walls or side screens; failing this, an exhaust of greater intensity will be necessry.

The side draught system maintains a constant rate of exhaust unaffected by the presence of large quantities of sand which frequently clog the knock-out grid, and operates directly on the rising column of dust-laden air so that this is drawn continuously away from the operators.

This type of exhaust deals only with the fine dust that is airborne above the moulds, and does not influence the heavier dust and sand which normally falls into the hopper below the knock-out. In this way the exhaust system is not subjected to heavy abrasive wear, which occurs when excessive quantities of sand are extracted; maintenance is therefore reduced, and the intial cost of the installation is less, as it is not necessary to employ such heavy gauge ducting. This system does not extract so large a proportion of the smaller fractions of the sand as does a down draught system.

A criticism often levelled at the side hood system is that it obstructs access to one side of the grid, but this limitation can frequently be overcome.

3. *Down Draught.* Down draught exhaust is effected by extracting air from the hopper or chute below the knock-out, either by nozzles extending along the length or

width of the hopper or by shrouded suction openings made in the sides of the hopper. The effectiveness of the down draught system depends on its ability to achieve a complete reversal of the upward flow of the thermal currents generated by the hot sand, moulds and castings before the dust and fumes can reach the breathing zone of the workmen.

(*a*) Its effectiveness is limited to small castings that produce thermal currents of low velocity and volume, contained in shallow boxes not exceeding 10-in. maximum height.

(*b*) The mould boxes must be standing on the knock-out grid and down draught alone will not be effective when boxes are knocked-out when suspended above the grid.

(*c*) The precise relationship of box size to grid size that can be effectively dealt with will vary both with the shape of the grid and the box, the position of the box on the grid, and the speed of the knock-out, which controls the rate at which the sand falls through the grid.

(*d*) Moulding boxes should not exceed one-fifth of the total area of the grid on which they rest and through which the down draught air is flowing, so that the falling sand cannot block the grid. This will ensure that the thermal currents rising above the centre of the box will be adequately influenced by the downward air movement.

The overall size of the knock-out grid used in a down draught system should not generally exceed 16 sq. ft. The box must, however, be placed centrally on the grid with ample space all round the box for the downward air flow.

This limitation on the size of the grid, together with restricted proportion of grid to box area, controls the maximum size of box that can be ventilated by a down draught system.

(*e*) The sand/metal ratio and the interval of time between pouring and knock-out should together ensure that only the sand adjacent to the casting is dry enough to release dust into the ventilating system.

A down draught ventilating system giving satisfactory control has the following advantages:

(i) The dust and fumes do not rise more than a few inches above the box and control is thus obtained close to the source.

(ii) There is no obstruction to access at floor level.

(iii) It is particularly suitable for highly mechanised foundries producing large numbers of small but uniform light castings.

The principal disadvantages of the down draught system are:

(i) It is restricted to small, light castings in shallow boxes which must be knocked out on a relatively large size grid.

(ii) The extraction of sand produces abrasion and the ventilating equipment requires more maintenance and cleaning than is usual with the side draught system.

(iii) The down draught system is not flexible and if the boxes or other factors exceed the upper limits of the design ratings, dust spillage will occur.

4. *Up Draught.* The up draught system with a canopy hood mounted directly above the knock-out prevents the escaping dust and fume from spreading into the general atmosphere of the foundry and offers no obstruction to access around the knock-out. It does not, however, afford any protection to the knock-out operators, as invariably the dust must travel through their breathing zone before reaching the hood. For this reason, this type of hood does not fulfil the design requirements outlined earlier. The air volume and freedom from interference with the constituents of the sand are comparable with those of the side draught system.

5. *General Ventilation.* In the case of general ventilation, increases in the concentration of dust in the general atmosphere of the foundry building can be limited only by effecting a specified rate of air change, by introducing fresh air at low level, and simultaneously extracting the fume-laden air at high level, and this affords no protection to the men working close to the source of dust. The general ventilation that is sometimes attempted by means of exhaust fans in the roof only is often less effective than the combined system, as a system comprising exhaust only can drawn dusty air from other parts of the foundry. General ventilation should only be employed in conjunction with local exhaust applied to each source of dust.

Floor Moulding

When considering the floor moulding of both large and small castings, it is not practicable to apply exhaust close to many of the sources of dust. Every effort must therefore be made to avoid the production of dust. As mentioned earlier, moulding sand will not form dust if the moisture content does not fall below half of that normally required for moulding in green sand, providing that the moisture is evenly distributed throughout the sand. If every effort is made to ensure that the moisture content does not fall below this level, the production of dust will be minimised.

The difficulty most frequently encountered is that hot castings lie in the sand and reduce the moisture content of the adjacent sand below the critical level. Hot castings should, therefore, be removed from the sand as soon as possible to a suitably ventilated cleaning station.

Castings made in dry sand moulds are difficult to treat in this manner. Some form of portable equipment might be considered for use when removing a casting from the mould. The casting should then be transported to a separate section for final cleaning. Any such portable exhaust plant must be arranged to discharge the dust-laden air outside the building.

Efficient exhaust could be most economically achieved by the introduction of one or more central knock-out plants and a sand distribution system, also exhausted as necessary.

When dealing with the floor moulding of large castings a substantial improvement in working conditions is possible if moulding positions can be maintained in lines, each served by the suction main of an exhaust system, to which flexible branch pipes could be temporarily attached adjacent to the moulding pit where work is in progress. This pit can be temporarily protected by the use of portable screens and hoods used in conjunction with the flexible suction pipe. The hood and pipe positions can also be easily moved to suit the progress of the work, thus affording protection to workers in the immediate vicinity, and reducing the spread of dust into the foundry building. The portable equipment can be easily moved from one pit to another.

The main suction ducts will need to be accommodated so that they do not interfere with the use of gantry cranes, and may either be underground or carried from the main building stanchions.

The alternative system comprises the use of underground ducts to the permanent moulding pits. With this system, the exhaust must be applied continuously to all the pits, whatever the stage of the work, and this requires a large and costly installation.

An independent system for each pit must otherwise be envisaged.

SUMMARY OF DUST CONTROL REQUIREMENTS

1. The most effective dust control is provided by complete enclosure of the knock-out.
2. In side draught systems a long side of the knock-out should be made available for the hood with sufficient space for an efficient form of hood. The side draught system is particularly flexible and suitable for less highly specialised foundries. In some circumstances hopper exhaust can be used with advantage to supplement side draught.

3. Up draught systems carry the whole of the extracted dust past the breathing zone of the operator, and can only offer protection if the operator is in such a position that replacement air diverts the stream away from his breathing zone.

4. Down draught systems can give satisfactory protection from dust and fumes produced by small castings in shallow boxes under the special conditions indicated.

5. General ventilation can do no more than keep down the dust and fume concentration in the foundry, and affords little protection to the knock-out operator.

6. Ventilation must not be an afterthought. It is part of the basic layout, and the plant designer must be prepared to co-operate with the ventilation engineer at an early stage, and to incorporate his recommendations in the plant arrangements.

7. If the moisture level of sand is kept at or above approximately one half that required for moulding it will not produce dust in any foundry operation.

APPENDIX VII

THE CONTROL OF DUST AND STEAM AT A MANUAL KNOCK-OUT

by H. B. DAUNCEY, M.I. POD.E., M.I.B.F. and W. B. LAWRIE, M.B.E., M.SC., F.R.M.S., A.I.M.

1. Dust and steam have been controlled at a small centralized manual knock-out grid by exhaust ventilation so arranged that the air is extracted at relatively high velocity through a slot mounted in a plate affixed to the side of the grid (Figure 5 and Plate 8). The installation is only suitable for small boxes up to 24-in. × 18-in. and it deals with more than the knock-out process but the results achieved appear to merit description as the system may be capable of wider application.

2. Small boxes are cast on a gravity conveyor and pushed along to the knock-out grid at the end. The grid is slightly higher than the conveyor so that the boxes can be turned over the ledge. As the box is manually inverted it falls on to the grid and the energy so imparted to it is sufficient to knock-out the casting. The drag and the cope are then lifted off and the casting is pushed across the grid at right angles to the line of the conveyor to fall into a truck placed beside the grid. The sand falls through the grid into a Royer and is wetted as quickly as possible. The Royer throws the sand into a pile over which a hood is mounted and the fan on the knock-out system also extracts air from this hood to control dust and steam from the heap of sand.

3. The fan has an inlet cone area of 302·45 sq. in. a discharge area of 274·0 sq. in. and runs at a speed of 1,443 revolutions per minute when it extracts 8,620 cu. ft. per minute. It is connected to the large hood over the sand pile from the Royer as well as to the knock-out exhaust system and experimental work has indicated that the knock-out exhaust takes from 40 per cent. to 60 per cent. of the total air volume depending on the dimensions of the slot. Originally a positive air curtain was blown across the knock-out from the side opposite to the exhaust slot but this was later discarded as being unnecessary. One end of the pipe supplying this air was retained over the box of hot castings lying in the pit beside the knock-out grid. This was kept to blow a cold air stream between the top of the box full of castings and the operator's face, in order to remove the convective heat from the castings and so provide more comfortable conditions. It was not intended to have any influence on the knock-out exhaust system. The slot mounted in the side plate is 72-in. by 4·75-in. and extracts 5,500 cu. ft. of air per minute at an intake velocity of 2,300 ft. per minute.

4. A cinematograph film was taken and Plates 9 to 13 are still photographs from the original 35 millimetre film negative. Plate 9 shows conditions when knocking out without exhaust and Plate 10 shows the conditions when the exhaust system was working. Plate 11 which was taken without the exhaust system shows the cloud of steam and dust just beginning to envelop the operator. At a later stage this cloud spread until it filled the operator's breathing zone. Plates 12 and 13 are the corresponding photographs with the exhaust system working. Plate 13 shows the cloud under normal control and indicates the relative position of the man. Plate 12 was taken just as the operator lifted the half box from the mould and a cloud of steam and dust was lifted with it to the extent shown in the picture. It can be seen that the edges of this cloud are still some distance from the operator's breathing level. This cloud which represents the maximum leakage observed in the experimental conditions imposed was brought under control again as soon as the box was clear of the slot and it never polluted the breathing zone of the man.

Appendix VIII

THE EXTERNAL DUST CONTROL SYSTEM (14-IN. STAND GRINDER)

1. The rapid dust estimation method[5] and the observation and cinematography of dust clouds[11] quickly showed that conventional local exhaust ventilating systems fitted to stand grinders were not always as successful as had been supposed. The original work[11] was done on a 24-in. diameter wheel which runs with a peripheral velocity of 9,000 feet per minute, and Plate 3 shows the conditions which were found. The fine dust, which had been generated by grinding, followed the wheel round and was ejected at high velocity from the guard opening at the top of the wheel. The bulk of the particles, which form this dust cloud, are less than 5 microns in diameter, and so are well within the respirable size range. In consequence, this dust stream had not been seen before, because the particles are so small as to be invisible in ordinary lighting conditions. The cloud, however, can be seen in Plate 3 which was taken from the early film negative, and it is clear that the conventional local exhaust ventilating system, which was operating when this photograph was taken, is not preventing the dust stream from leaving the wheel hood and moving across to strike the operator in the chest as it rises to his face. When these observations had been completed, the Foundry Atmospheres Committee decided that the matter should be investigated more fully and that, as the early work had been done on a 24-in. diameter wheel, it was desirable to explore the effects on a smaller wheel running at a lower velocity. As a result of this decision, the work was undertaken for the Foundry Atmospheres Committee, by Mr. W. H. White of the British Cast Iron Research Association and Mr. W. B. Lawrie, a member of our Committee, and the original work was published in 1952[13], when it had been discovered that the smaller slower wheel showed similar aerodynamic characteristics to the larger one.

2. The workers, after a close examination of the earlier published work, drew the following conclusions[13]:—

"(1) It was desirable to devise new and more efficient means of dust control for pedestal grinders.

(2) The use of a high velocity low volume air curtain might be more efficient and would, in any case, offer the advantage of a lower air volume with a corresponding reduction in air losses and heating costs.

(3) Conventional dust extraction methods might not be capable of reversing the high velocity air stream developed by the wheel, which had been shown to carry the dust out of the cowl. If this were true, the fan effect of the wheel would have to be considered as an integral part of the extraction system.

(4) More fundamental information was needed with reference to the direction and velocity of the air current set up in the working area of an abrasive wheel rotating in space."

3. The experimental work was commenced on a 14-in. × 2½-in. wheel rotating at 1,400 revolutions per minute with a peripheral velocity of 5,000 feet per minute, and fitted with a normal type of dust extraction unit. The early work was directed towards the elucidation of the aerodynamics of the system, and the workers explored the zone of influence of the rotating wheel by means of the observation and photographic method[11], as well as by the measurement of air velocities taken with a Metropolitan Vickers Velometer. The observations were made both with and without the conventional local exhaust ventilating system in order to estimate the effects of the wheel itself, and also the effect of the ventilating system on it.

4. The first cinematograph film showed that the dust distribution from the wheel conformed to the general pattern discovered on the 24-in. diameter wheel[11], and Plate 14 shows the primary dust stream flowing down the wheel face, along the work, and up the operator's body towards his face. This photograph which is comparable with Plate 3

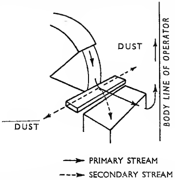

Figure 6. Dust streams requiring collection if the extraction system is to be efficient.

Illustration by courtesy of the Institute of British Foundrymen

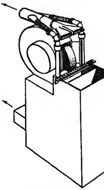

Figure 7. Prototype fitted with nozzles.

Illustration by courtesy of the Institute of British Foundrymen

was taken when the conventional local exhaust ventilating system was fitted and operating. The dust streams which had been observed and photographed were then explored by means of the Velometer. Plate 15 shows the air movement due to the rotation of the wheel itself when the local exhaust system was not in action, and so represents the aerodynamic effects of the rotating wheel. It is quite obvious from Plate 15 that the wheel acts as a fan, and that this effect should not be ignored when designing dust control systems. The workers finally showed that the dust streams indicated in Figure 6 would have to be collected if the local exhaust system was to be efficient, and at this stage of the work they reached the following conclusions[13]:

"(1) That much of the dust followed the wheel round and was ejected at high velocity at the cowl opening.

(2) That conventional local exhaust ventilation systems appeared to be incapable of reversing this dusty air stream and so controlling the dust.

(3) That between the cowl and the face of the operator, there was a zone penetrated by sundry air currents.

(4) That these currents moved at relatively low velocity.

(5) That this zone included at least two neutral points at which no air movement could be recorded."

5. The work showed, therefore, that the primary dust stream, which flowed down the wheel face at velocities up to 3,000 ft. per minute, was not being reversed by the conventional local exhaust system, on account of its high velocity. It was also clear that it could be more easily controlled after decelerating outside the wheel hood by means of relatively low volume air streams provided they moved at a sufficiently high velocity. The secondary air streams shown in Figure 6 would also have to be collected, and so the two investigators proceeded with a design which incorporated the following features[13]:

"(1) A high velocity low volume curtain was to be used.

(2) The extraction system was to be external to the wheel cowl and collecting box.

(3) Provision was to be made to collect the dust which flowed along the rest parallel to the wheel axis.

(4) Provision was to be made to collect the heavier dust, together with any dust which might leave the work rest or the castings in a downward direction and move towards the feet of the operator."

6. The conventional exhaust system was completely removed from this small wheel, and the dust produced by grinding was allowed to leave the wheel cowl before being collected. The new local exhaust ventilation system that was developed operated therefore externally to the cowl, so that it became known as " the External Dust Control System". The final prototype is shown in Figure 7. In this machine, the primary dust stream was collected through the nozzle mounted above the wheel hood; the secondary stream, which flows along the work rest, was collected through the two vertical pipes placed one on each side of the wheel; and the hopper in front of the rest served to collect the heavier particles, which were projected downwards from the work. The ventilating air entered the top nozzle at a velocity of 5,000 ft. per minute, and entered the side ducts at a velocity of 3,500 ft. per minute, while the velocity at the rim of the small hopper was 1,000 ft. per minute. The total air volume used on this machine was about 450 cu. ft. per minute.

7. The development work was based on the movement of the dust clouds which were recorded on a 35 mm. cinematograph film, and the efficiency of the new external dust control system can be seen from Plates 16 and 17, which are reproduced from the original film negative. The inefficiency of the conventional local exhaust system, which was discarded is apparent from Plate 14, and Plate 16 shows the wheel operating on

grey pig iron without local exhaust ventilation. Plate 17 shows the standard of dust control obtained with the new external system fitted and fully operative, and with grey pig iron still being ground, as in Plates 14 and 16. The observations and the photographs were confirmed by dust counts taken with an Owens Jet Counter and with a Thermal Precipitator. Details of the dust counts were published in the original paper[13].

8. The two research workers drew the following conclusions[13]:

"(1) It has been shown that the phenomena found on a grinding wheel running with a peripheral velocity of 9,000 ft. per minute, which were described in a previous paper[11], also appear on a wheel running at a peripheral velocity of 5,000 ft. per minute.

(2) The primary dust stream, which flows down the face of the rotating wheel and sundry secondary air streams, which develop therefrom, have been photographed by means of a cinematograph camera.

(3) The necessity for dust-tight dust collectors has been shown by photographs of a dust cloud of about 2,000 particles per cu. cm., which was found to be leaking continuously from a collector unit, which was under pressure from the fan.

(4) It has been found that, in cases where the dust moves in well defined streams, dust samples taken in standard conditions, when the dust is invisible, may give erratic results. It appears that these variations in the results are often due to the fact that the instrument may fail completely to sample the main dust stream, and may be collecting from a much cleaner air stream moving alongside the dust stream. It appears, therefore, that visual dust observations are desirable to supplement dust counts.

(5) Observations have shown that the dust control achieved by the new external exhaust system is superior to that obtained by the conventional method of ventilation, in the experimental conditions imposed. Even when heavy dust clouds momentarily burst through the high velocity air curtains, the dust was quickly recaptured by the system.

(6) Observations have suggested that nozzles are at least as good as, if not better than, the long extraction arms.

(7) Thermal Precipitator dust counts have shown that the new system is capable of controlling dust clouds, so that the breathing zone concentration remains below about 750 particles per cu. cm., even when the dust cloud generated is of the order of 60,000 particles per cu. cm. In these conditions of gross overload, the average breathing zone dust concentrations lay between 400 and 500 particles per cu. cm."

Appendix IX

THE COMBINED DUST CONTROL SYSTEM (24-IN. STAND GRINDER)

1. After the external dust control system[13] described in Appendix VIII had been fitted to a 14-in. diameter wheel running at a peripheral speed of 5,000 ft. per minute, the Foundry Atmospheres Committee decided that the aerodynamics of a 24-in. diameter wheel, with a peripheral velocity of 9,000 ft. per minute, should be explored. Once again the investigations were undertaken by Mr. W. H. White, a member of the British Cast Iron Research Association and Mr. W. B. Lawrie, a member of our Committee, and the work was done in the laboratories of the British Cast Iron Research Association[14].

2. In the first instance, the external system, which had been developed on the 14-in. diameter wheel[13], was applied to the 24-in. diameter wheel as it stood[14]. The standard dust collecting box fitted to the larger wheel was, however, too small to release the pressure generated by the running wheel. In consequence, the dust was blown out of the collecting box and the external system was overloaded to such an extent that it did not give adequate dust control. It was evident that the pressure in the collecting box must be relieved, and it was decided to do this by connecting it to the fan in the conventional manner. This resulted in the combined dust control system which is shown in Plate 18 (a). The exhaust duct in the back of the dust collecting box releases the air pressure set up by the fan effect of the wheel and also extracts some of the dust. The external part of the system applied over the top and down each side of the wheel collects the dust which either leaves or fails to enter the wheel guard. In addition to these arrangements, the work rest was perforated and mounted directly on top of the collecting box. This was done so that dust could be collected through the perforated rest, if the work was small enough to leave part of it uncovered. It was found, however, that the system would still work satisfactorily even if the perforated rest were covered, because in these circumstances the external part of the system took a larger proportion of the dust.

3. The machine was tested in laboratory conditions using a 24-in. diameter wheel, and a 16-in. diameter wheel. The smaller wheel was used in order to estimate the effects of wheel wear on the efficiency of the ventilating system. Neither the observation technique nor the Thermal Precipitator dust counts showed any significant difference in dust concentration (at the breathing level of the operator) between operating conditions and general atmospheric conditions before commencing work. This indicated the efficiency of the prototype, and the conclusion was valid both on a new wheel of full diameter and on the worn wheel, which was only 16-in. in diameter. The combined system in the conditions obtaining at the time was, therefore, controlling all the dust generated by the grinding process. The Thermal Precipitator counts were not incinerated in order to retain all the dust produced, and they were counted in standard conditions on an optical microscope, counting all particles down to the limit of visibility in light field illumination.

One further point of interest emerged from the test. Grinding machines are normally fitted with an adjustable flap at the guard opening at the top of the wheel. This flap is adjustable so that it can be lowered as the wheel wears in order to maintain a minimum gap between the guard and the wheel top. In practice, however, this adjustment is not always made as carefully as it should be, and in the conventional local exhaust system it may affect the efficiency of the dust control. The tests on the combined exhaust system, however, showed that the magnitude of the gap between the wheel top and the guard did not influence the efficiency of dust control. Even when the gap was deliberately increased to 4½-in. × 3½-in., by using a 16-in. diameter wheel, the experimental system still retained control of the dust.

Full experimental details have already been published[14]. Plate 18 (b) however showed that the smoke produced by grinding wood can be controlled by the system. This observation may not be applicable to the dust produced when grinding metal but it serves to indicate the efficiency of the system on very small particles. Plate 19 shows the combined system with the worn 16-in. diameter wheel being used to grind grey iron. The dust cloud is being cut off at the level of the top nozzle, well below the breathing zone of the operator and the system has good control over the dust in spite of the large gap between the wheel top and the guard.

4. The work on the 24-in. diameter wheel led the authors of the original paper[14] to the following design and conclusions:

Design

(1) A perforated work-rest was mounted directly on the top of the collecting box.

(2) The pressure in the collecting box was relieved and some of the dust collected by applying part of the ventilating air in the conventional manner through a duct fitted to the back of the collecting box.

(3) The external system was fitted to the top and sides of the wheel to collect the dust which either left or failed to enter the wheel guard.

Conclusions

" (1) The combined exhaust system gave very good dust control when the machine was fitted with a 24-in. diameter wheel.

(2) The gap between the wheel top and the guard did not influence the efficiency of the dust control. Even when this gap was increased to 4½-in. × 3½-in. by using a 16-in. diameter wheel, the experimental system still retained control of the dust.

(3) Neither the observation technique nor the thermal precipitator counts showed any measurable difference in dust concentration (at the breathing level of the operator) between operating conditions and general atmospheric conditions, before commencing work. This conclusion, which is valid for both the 24-in. diameter wheel and the 16-in. diameter wheel, indicates the efficiency of the prototype operating under the experimental conditions imposed during testing."

Appendix X

LOW VOLUME HIGH VELOCITY DUST CONTROL FOR A PORTABLE GRINDER

1. Very heavy dust concentrations may be developed by the use of portable grinders, and much of the dust so produced will be within the respirable size range. It may be possible to put small work onto a bench, which can be fitted with local exhaust ventilation, but much of the work which is ground by portable machines is either too big or too heavy to be treated in this fashion. In consequence, portable grinders have often been used without dust control and the effects of this method of working appear in the dust concentration figures to which reference has already been made[7]. The Joint Standing Committee on Conditions in Iron Foundries therefore decided that this matter should be investigated, and in consequence, two members of an industrial firm, Mr. A. T. Holman and Mr. E. B. James, and a member of our Committee, Mr. W. B. Lawrie, together began research work on the problem in 1953. Their object was to develop a dust control system which would provide protection from the dust and, at the same time, form an integral part of the portable machine. It was quite clear from the outset that the proposed dust control system would have to be inconspicuous and very light in weight, so that the portable machine would retain its flexibility of operation, and, as this was the first time that any attempt had been made to exhaust dust through the guard of a hand grinder, the investigators had no previous experience to guide them. They began, therefore, by examining the aerodynamics of the machine by means of the dust observation technique.

2. The preliminary work was done on a Series 40 Holman Grinder, fitted with a 6-in. diameter wheel with a free running speed of 6,000 revolutions per minute and a peripheral speed of 9,000 ft. per minute. A 5-in. diameter wheel was also used during the tests in order to estimate the effect of wheel wear[16]. The prototype is shown in Plate 20. The wheel guard was fitted with a peripheral duct which conformed to its curved edge, and three ports opened on the inside curved surface of this duct, which was also connected to a ⅜-in. diameter flexible pipe. In the experimental work the exhaust was obtained from a compressed air eductor as illustrated in Figure 1. The fine dust can be seen above the wheel as it diffuses upwards to the operator's breathing level. Plate 21 was taken from the cinematograph film negative that was used during the development of the new low volume high velocity exhaust system. It shows the fine dust under good control even in the worst conditions with the leading edge of the hood lifted as far above the work as possible. The wheel is rotating in an anti-clockwise direction and is grinding grey iron. Heavy particles can be seen falling to the floor, but the main dust cloud is under good control. The dust which has passed the leading edge of the guard on the right is being brought back by the induced air stream.

3. Preliminary dust counts were also taken in laboratory conditions[17,18]. The Owens Jet Counter showed a general atmospheric dust concentration of 200 particles per cubic centimetre before starting work. This rose to 300 particles per cubic centimetre at the breathing level of the operator, after he had been grinding grey iron for seven minutes

with the new exhaust system working. Without the exhaust system, seven minutes' grinding gave a dust concentration of 10,000 particles per cubic centimetre in the operator's breathing zone. Comparable results were obtained with the Konimeter. This instrument produced no recognisable spot from the general atmosphere before starting work. Grinding grey iron for seven minutes with the exhaust system fitted and operating lifted the breathing level concentration to 78–120 particles per cubic centimetre, while a similar grinding period without exhaust produced a Konimeter sample that was too dense to count. The Thermal Precipitator showed 139 particles per cubic centimetre in the general atmosphere in the laboratory before work started. With the exhaust system working, the breathing level concentration rose to 243 particles per cubic centimetre, but a similar grinding period without the exhaust system produced 3,278 particles per cubic centimetre.

4. The following conclusions were reached by the research and development workers who completed the project:

(1) Dust control by local exhaust ventilation could be fitted to portable grinders.

(2) A very low volume of ventilating air moving at a very high velocity under a high vacuum is necessary on the portable grinder. This is a new conception in ventilating practice.

(3) The moving dust can be stripped from the face of a rotating wheel inside the guard. This result was achieved by the use of a peripheral duct fitted with three ports through which about 24 cu. ft. of free air per minute was extracted at a vacuum head of about 5-in. of mercury.

(4) The small ducts which are essential on hand tools to allow sufficient flexibility of movement result in air velocities of the order of 12,000 ft. per minute inside the duct.

(5) The exhaust air may be induced either by a compressed air ejector, or by a rotary exhauster, or by a suitable fan.

(6) The use of a compressed air jet to strip the dust from the wheel face was found to be both unnecessary and unsuccessful.

(7) A compressed air jet can be used to increase the amount of air induced into the system. Great care is needed in the adjustment of this jet if it is not to do more harm than good. The development work showed it to be unnecessary, and so it was discarded.

5. The hood on which the system was developed covered a large proportion of the wheel face, and in consequence will be impracticable on certain work. The original work had, however, provided a dust control system, which was useful enough in some cases; it had shown that the dust could be controlled from portable grinders, and it had established a new principle in local exhaust ventilation. In consequence, another group of workers consisting of Mr. A. T. Holman and Mr. F. F. L. Morgan of an industrial firm, and Mr. W. B. Lawrie from our Committee, undertook to investigate the problem of applying the new system to the various circumstances in which portable grinders might be used. They first cut back the hood until it covered little more than half of the wheel and, at the same time, they succeeded in retaining control of the dust. The next step was to remove the hood when it was discovered that the dust could be controlled through a curved peripheral duct which extended over about a third of the wheel circumference[19]. Once again the dust was kept under control. Finally, an extractor head was developed so that the wheel could be worked without guard altogether, and the maximum amount of wheel face exposed for grinding[20]. The head can be seen in operation in Plate 22. It is provided with a port on its inner surface to which has been added an aerofoil vane so that the dust is stripped from the wheel face. Heavier dust particles and sparks flow along the line of the work tangentially to the wheel face, and this stream of sparks and dust is collected through a second port in the lower surface of the extractor head. A roller device has been fitted to the front of

the head so that it will run more easily over the work, and as the tangential stream of dust and sparks strikes this roller, it decelerates before being collected by the port immediately above it. The head can be adjusted quite simply to all wheel diameters from 8-in. down to 2½-in., so that it can be kept in close proximity to the wheel as it wears. The prototype was constructed for a wheel 1-in. wide and it extracted 40 cu. ft. of free air per minute at a vacuum head of 5-in. of mercury through a ¾-in. plastic hose.

The machine was developed by means of the observation and photographic technique and Plates 22 and 23 indicate the measure of dust control that was achieved. Plate 23 shows a 6-in. by 1-in. wheel grinding grey iron in laboratory conditions without exhaust ventilation and Plate 22 shows the same wheel grinding the same material in the same conditions but with the new extractor head fitted and operating. It will be seen that a few sparks leave the system still, but that the main dust cloud is now under control. Dust counts taken by means of the Thermal Precipitator, the Konimeter and the Owens Jet Counter confirmed the visual observations and the photographs[20].

APPENDIX XI

LOW VOLUME HIGH VELOCITY DUST CONTROL FOR A BENCH GRINDER

1. The successful development of the low volume high velocity local exhaust ventilating system for a portable grinder led the research workers to consider again the problem presented by stand grinders. Since dust could be controlled on a 6-in. diameter portable wheel with an air volume as low as 23·5 cu. ft. of free air per minute, it appeared that a similar system might be developed for stand grinders, and it was clear that the low air volume would offer certain advantages in practice.

Work was therefore commenced[17 18] on a 6-in. diameter bench grinder which was used to grind tools and small articles. The machine was, in fact, a very small stand grinder fitted with an ordinary work-rest and bolted to a bench. In the first instance, the workers tried to apply the exhaust through a peripheral duct similar to that developed for the original portable grinder. It was found, however, that the system did not satisfactorily control the dust on the 6-in. diameter bench grinder running at a free speed of 6,000 revolutions per minute with a peripheral speed of 9,000 ft. per minute.

2. This preliminary experimental work led the investigators to an examination of the aerodynamics of the system by means of the illumination techniques, and this resulted in a new design of port opening in the peripheral duct. The position of the two ports was altered, and aerofoil vanes were added in the port openings both to improve the dust control and in an attempt to utilise the fan effect of the wheel itself. All rotating wheels act as fans and it was thought that the power that was available in this fan effect should be used. The redesigned system was then applied to an 8-in. diameter wheel[17 18] and it was found that the new ports with the aerofoil vanes did, in fact, use the fan effect of the wheel to such an extent that it pumped air down the duct at velocities from 1,000 ft. to 1,900 ft. per minute depending on the wheel diameter.

3. Once again, as a matter of convenience, in the early work the vacuum was induced by a compressed air ejector, although a rotary exhauster or a suitable fan could be used for this machine. The air ejector was modified so that it induced about 40 cu. ft. of free air per minute at a vacuum head of 3-in. to 5-in. of mercury. In the final prototype the peripheral duct inside the guard was fitted with two offtake ports in its lower half. A ⅜-in. diameter flexible pipe was taken from each offtake and joined through a "Y" piece to a single flexible hose which was connected to the air ejector. The arrangement can be seen from Plate 24.

4. The machine was tested when grinding steel, grey iron, wood and a second wheel chosen to produce a very dense dust cloud. The air velocities generated in the vicinity of the wheel were explored by means of a Velometer when using wheels which varied in diameter from 4-in. to 8-in. both with and without the local exhaust ventilating system. The object of these tests was to determine the effect of wheel wear on th exhaust system, and to estimate the efficiency of the system on different size ranges dust in widely varying concentrations. The final tests were done in conditions of gro overload, which would rarely be met in normal practice.

5. Plates 25 and 26 were taken from the 35 millimetre film negative which was used for the development of the system[17 18] and they show the efficiency that was attained when grinding grey iron. Plate 25 shows the machine running without exhaust ventilation, while Plate 26 is the corresponding picture with the new ventilating system fitted and operating. The dense smoke streams which are produced when grinding wood were completely controlled by the system and no smoke left the wheel hood when it was in use. It must be appreciated that the paths taken by the smoke particles may not coincide with those taken by dust from normal grinding operations, but the use of smoke served to indicate the efficiency of the system on very small particles. Finally, a second abrasive wheel and a piece of steel were ground and in the optical settings used no visible dust left the system.

6. A short series of dust counts were taken in laboratory conditions, using an Owens Jet Counter and a Thermal Precipitator[17 18]. The samples were not incinerated and the wheel was used to grind steel, grey iron and another wheel. The results confirmed the observations and indicated that the exhaust system was controlling all the dust generated, as there was no difference in dust concentration at the operator's breathing level whether he was grinding or not.

7. The completion of this project led the research workers to the following conclusions[17 18]:

(1) The low volume high velocity exhaust system has been applied to an 8-in. diameter bench grinder.

(2) The fan action of the wheel itself has been used to produce a velocity of 1,000 ft. to 1,900 ft. per minute in the ventilating duct apart from that given by the applied vacuum.

(3) The new system appears to be sufficient to reverse the primary air stream which has been shown to flow down the face of grinding wheels. An air intake was measured at the guard opening at the top of the wheel where all previous work had shown air flowing out of the guard.

(4) The dust control system used 46 cu. ft. of free air per minute at a vacuum of 3-in. of mercury.

(5) The vacuum can be induced either by a compressed air ejector or by a rotary exhauster or by a fan.

(6) The dust control achieved was observed by the illumination technique and estimated by a short series of dust counts made on Owens Jet Counter and Thermal Precipitator samples. In the laboratory conditions imposed during the tests, the new exhaust system controlled all the dust generated by the grinding process.

Appendix XII

LOW VOLUME HIGH VELOCITY DUST CONTROL FOR A PORTABLE SURFACE GRINDER

1. Large surfaces are often ground by means of a portable surface or disc grinder in which the side of the wheel is used for grinding, and not the edge. These machines frequently produce very dense dust clouds the control of which has been a matter of great difficulty. Various kinds of hoods and booths have been tried, but because the articles being worked are often large and the surfaces to be ground are awkwardly placed, it has proved impossible always to ensure that the operator will never work between the point of dust generation and the exhaust hood. As a result, even when hoods have been used, the dust has often been extracted through the operator's breathing zone. In these conditions a hood may serve some purpose in extracting dust which would otherwise contaminate the general atmosphere of a building, but it has little value to an operator who must breathe the dust-laden air as it passes his head.

2. The problem was put by a foundryman to a member of the Joint Standing Committee on Conditions in Iron Foundries and, as a result, research was begun on it by Mr. A. T. Holman and Mr. E. B. James, of an industrial organisation, together with Mr. W. B. Lawrie of our Committee[18]. The illumination technique was used to explore the dust movement generated by the wheel, to develop the dust control system and to estimate the efficiency of the completed unit, and the low volume high velocity system was again applied. In the experimental work, the ventilation air was once more induced by an air ejector but a rotary exhauster or fan could be used equally well.

3. The first prototype is shown in Plate 27, from which it will be seen that the wheel is surrounded by a ring through which the exhaust air is extracted by a $\frac{5}{8}$-in. diameter flexible hose which was coupled to the compressed air ejector. This ejector extracted 28 cu. ft. of free air per minute at a vacuum head of 4 in. of mercury, and the dust photographs in Plates 28 to 31 were taken from the original 35-mm. film negative which was used during the development work[18]. Plate 28 shows the normal operating conditions when grinding a bath without exhaust ventilation, while Plate 29 is the corresponding photograph with the new local exhaust system fitted and operating. It will be seen that no visible dust is leaking away from the system. Plate 30 shows the machine in use on the edge of a grey iron casting and the exhaust system was operating when this photograph was taken. It is included to show the level of dust control that can be achieved even when the wheel is in contact with the work at two points only. If the wheel is used with one point of contact only, as in Plate 31, there is a very slight leakage of dust.

4. This first prototype was tested in laboratory conditions when grey iron was ground and dust samples were taken with an Owens Jet Counter and a Thermal Precipitator[18]. Both these instruments indicated that the exhaust system was controlling all the dust generated. The tests were not sufficiently prolonged to determine whether or not there

would be any increase of dust concentration at the breathing level during a full day's work, but taken in conjunction with the results of the illumination technique, the tests indicated a high level of dust control.

5. The machine is now in use in industry, but the research and development project produced the following conclusions:

(1) It has been shown that local exhaust ventilation can be applied to portable surface grinders.

(2) The low volume high velocity system has been satisfactorily adapted to work on this type of machine.

(3) The exhaust air can be induced, either by a compressed air ejector or a rotary exhauster or fan.

6. When the first project had been completed, a different team of workers consisting of Mr. A. T. Holman and Mr. F. F. L. Morgan from an industrial firm with Mr. W. B. Lawrie of our Committee, decided to explore the possibility of removing part of the exhaust ring. In the first successful machine, the exhaust air was extracted through ports placed all round the inner edge of a ring, which completely surrounded the wheel. Further work[20] has now shown that this ring does not need to encircle the wheel, and the dust can still be controlled if a section of the duct is cut away as shown in Plate 32. This modification allows the operator to see part of his wheel and also facilitates the use of the wheel close up to projections and in corners.

7. Plate 33 shows the machine being used to grind grey iron without local exhaust ventilation, and the dust cloud can be seen as it leaves the wheel. Plate 34 is the corresponding photograph taken when the wheel was still being used to grind grey iron, but with the new exhaust system fitted and operating. A few sparks can be seen leaving the work, but the main dust cloud is now under control. The modified ventilating system extracted 33 cu. ft. of free air per minute at a vacuum head of 5-in. of mercury and dust counts taken in laboratory conditions when the machine was in use on grey iron confirmed the observations and indicated a high level of dust control[20].

APPENDIX XIII

AN INTEGRAL EXHAUST SYSTEM FOR SWING FRAME GRINDING MACHINES

British Steel Castings Research Association

Introduction

1. In its studies of the problem of dust control on swing frame grinders, the British Steel Castings Research Association has recognised three distinct and well-established methods which can be defined as follows:

(1) to embody a local exhaust system in the swing frame grinder unit itself;

(2) to conduct the grinding operations over or adjacent to a grating through which dust laden air can be extracted;

(3) to operate the swing frame grinder in front of a booth that is coupled to an extraction system.

While each of these three methods was subjected to critical examination with the object of assessing their relative efficiencies and advantages, the main experimental work was concentrated on method (1), *i.e.* an exhaust system integral with the swing frame grinder machine.

Dust Flow Characteristics

2. A series of observations was carried out both in the B.S.C.R.A. Dust Research Station and under industrial conditions, of the dust flow characteristics of various types and sizes of swing frame grinding machines as a preliminary to original experimental work in this field.

Throughout these studies the observations of dust flow and the detection of dust have been based upon the Lawrie method of illuminating airborne dust, which enables the dust of respirable size range to be seen and photographed. Cinematograph film records were made throughout the experimental work.

Various types of swing frame grinders commonly used in the steel founding industry show the same characteristic pattern of dust flow, consisting of a primary stream of dust ejected tangentially from the point of its generation and a secondary stream of dust emerging from the wheel guard.

The primary dust stream consists of particles of a very wide range of sizes. Large particles are of no importance from the point of view of the health hazard, but their influence on the flow of fine dust has to be considered. When grinding different materials, *i.e.*, wood, steel castings, and rusty pig iron, it became evident that the nature of the material being ground has an influence upon the behaviour of the primary dust stream in particular. These observations have shown that where a proportion of relatively large particles is produced by the grinding operation, these particles, due to the kinetic energy imparted to them on their formation and release, follow a straight path tangential to the wheel for a considerable distance (several feet), and that they in turn induce some of the fine dust to follow in the same path and to remain in the primary stream.

The secondary dust stream is brought around with the slipstream produced by the rotating grinding wheel, is discharged into the general atmosphere and may reach the operator's breathing zone. Whether it reaches the operator's breathing zone as a cloud of high concentration depends upon the position of the operator (in particular upon the position of his head), in relation to this stream of dust, and upon the contour of the casting that is being ground. The effect of the shape or contour of the casting being ground is evident, as this secondary stream, on leaving the hood, is directed downwards, and, depending upon the position of the grinding machine relative to the casting will either continue unobstructed until it reaches the floor or will be deflected and spread either sideways and, in many cases, partially upwards, depending upon the configuration of the obstruction, *i.e.*, the casting or bench, which it may meet.

Experimental Considerations

3. The object of the work described in this paper has been to develop a device or modification that can be applied to new as well as to existing swing frame grinding machines in foundries, preferably involving a minimum cost and a maximum of simplicity.

Stages of Development

4. In various stages of the experimental work the following alterations to the wheel guard were made:

(i) Closing the gap between the sides of the wheel and the hood.

(ii) Closing the opening at the front of the hood with a plate adjustable to the wheel wear.

(iii) Fitting an attachment, which formed an extension to the back of the hood. This extension built in the shape of a box had two intake-openings in the underside. The intake nearest to the wheel (which is an extension of the slot accommodating the grinding wheel) admits the slip-stream that carries the dust forming the secondary dust stream. The second intake was placed further away from the wheel to bring under control the fine dust entrained in the primary stream. Both intakes were provided with sliding covers to allow easy adjustment to the size of the openings.

(iv) Removing a portion of the back plate of the wheel hood, to produce a continuous internal cavity within the original hood and the "box" attachment. The orthodox hood was thus brought within the influence of the exhaust system.

(v) Fitting horizontal flanges to the lower edges of the "box" attachment. These flanges were extended towards the "front" of the wheel and also in the opposite direction beyond No. 2 intake.

Figure 8 (a) shows the design that was finally evolved as a result of the experimental work.

Figure 8 (a). Development Stage 4, showing the position of intakes and the extended flange.

Illustration by courtesy of the British Steel Castings Research Association

5. *Conclusions*

(1) A system of dust control, equally applicable to existing or to new swing frame grinding machines has been developed (this system has been protected in the name of the Association by provisional patent No. 35971/53).

(2) Extended Dust Research Station trials under varying conditions of grinding have shown that the system provides an effective control of dust, when assessed by the Lawrie illumination technique for airborne dust detection (Plate 35).

(3) The system, which is simple in design and relatively cheap to construct, has been shown to be effective when applied to a standard machine with 16-in. diameter grinding wheel operating at a peripheral velocity of 9,000 ft. per minute, to which the following modifications were introduced: (Figure 8 (b).)

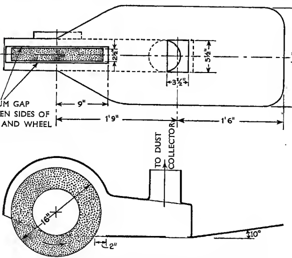

Figure 8 (b). Design of the exhaust hood, showing the sizes and positions of the intakes and the flange.

Illustration by courtesy of the British Steel Castings Research Association

(*a*) closing the gaps between the side plates of the hood and the sides of the grinding wheel,

(*b*) intake No. 1, nearest wheel, should be 2 in. long (with 16-in. diameter wheel fitted),

(*c*) intake No. 2 should be 3½ in. long by 5½ in. wide and positioned so that its centre line is 1 ft. 9 in. from the centre of the grinding wheel,

(*d*) the flange should extend from the axis of grinding wheel to a distance 18 in. behind intake No. 2 and should be a of total width of 18 in. so that it projects not less than approximately 6 in. on either side of the side plates of the hood,

(*e*) the driving belt should be encased.

4. For an effective dust control an exhaust rate 900 cu. ft. per minute at 3¾ in. w.g. static pressure is required.

Appendix XIV

LOW VOLUME HIGH VELOCITY DUST CONTROL FOR A SWING FRAME GRINDER

1. The development of the low volume high velocity system for portable tools led a foundryman to approach a member of our Committee with the request that it be adapted for use on swing frame grinders. The system would, of course, use less air than other methods and this would offer some advantage in a foundry, but what was perhaps more important was that the small diameter ducting would allow full flexibility to the machine. This is, of course, a matter of great importance in the operation of swing frame grinders. The necessary research work was undertaken once again by Mr. A. T. Holman and Mr. E. B. James of an industrial firm, and Mr. W. B. Lawrie of our Committee[18].

2. The wheel guard was first fitted with a peripheral duct which had a port in the leading edge (*i.e.*, the edge towards which the wheel face moves as it leaves the point of contact with the metal), a port in the trailing edge, and two intermediate ports. This gave reasonably good dust control, but the system was greatly improved by an inlet duct fitted with three ports and placed at the leading edge. All the ports were provided with vanes to use the fan effect of the wheel itself. The early experimental work was done in a laboratory where it was convenient to induce the vacuum by means of compressed air ejectors. The exhaust system on the final prototype, however, was run from a fan which extracted 250 cu. ft. of air per minute at a vacuum head of 3 in. of mercury. The peripheral duct in the guard was connected to the fan by a 3-in. diameter hose.

3. The whole of the development work was again based on observations made by the illumination technique, and Plates 36 to 38 are photographs taken from the cinematograph film negative which was used for the original work[18]. Plate 36 shows the dust cloud produced by grinding a grey iron casting without exhaust ventilation. Plate 37 is a corresponding photograph taken when the new system was fitted and operating. The machine has been swung away from the operator, so that the leading edge of the guard on the right is over the floor and no physical barrier is present to prevent the dust from flowing away from the port openings in the duct. Even in these conditions the exhaust system completely controls the dust generated by the wheel. The dust is also under control at the trailing edge of the guard on the left where the trailing port is being assisted by the presence of the casting below it, which serves to keep the dust within the vicinity of the port until it has been collected. It is noticeable that even the heavier particles and the sparks are being influenced by the system at the leading edge of the guard on the right. Plate 38 was taken when the machine was in use on the edge of the casting nearest to the operator who is out of the picture on the left. Conditions are, therefore, somewhat different from those illustrated in Plate 37. In Plate 38, the trailing edge of the guard on the left is over the floor, so that any dust which leaves the guard at this point is free to flow away without physical obstruction.

Nevertheless, the exhaust system is giving good control at this trailing edge. The dust cloud moving from the point of origin towards the leading edge of the guard on the right is also under complete control. Photographs were also taken when grinding steel and wood, and they showed similar effects.

4. The results of the illumination method were confirmed by dust counts, both on the Owens Jet Counter and on the Thermal Precipitator[18]. The samples were taken when the machine was being used to grind grey iron in laboratory conditions. The tests were not extensive enough to determine the effects of a full day's work in the conditions of an ordinary dressing shop, but they showed no increase in dust concentration at the breathing level of the operator during the period they covered. This means that the new system was controlling all the dust that was generated. When taken in conjunction with the observation technique and the photographs, these tests indicated a high level of dust control.

5. The machine is now on trial in a dressing shop, but the experimental work led the investigators to the conclusion that the dust from a swing frame grinder could be controlled by 250 cu. ft. of free air per minute at a vacuum head of 3 in. of mercury, using flexible ducts as small as 3 in. in diameter.

(69166)

Appendix XV

LOW VOLUME HIGH VELOCITY DUST CONTROL FOR A TRANSVERSE SWING FRAME GRINDER

1. When the work had been completed on the normal type of swing frame grinder, another foundryman approached a member of our Committee with the request that the system be adapted, if possible, to a transverse machine in which the wheel spindle is in line with the machine boom so that the wheel itself runs at right angles to the line of the boom. The research and development project was undertaken by a slightly different group of workers consisting of Mr. A. T. Holman and Mr. F. F. L. Morgan from an industrial firm, and Mr. W. B. Lawrie, who is a member of our Committee[20].

2. The research workers decided not to use the peripheral duct on this machine, but adapted instead the extractor head which had, by this time, been developed for the edge running portable grinder (*see* Appendix X). The head, which was twice the size of the one used on the portable grinder, extracted 150 cu. ft. of free air per minute at a vacuum of 5 in. of mercury, and it was connected to an extraction plant by a lightweight hose of $1\frac{1}{2}$ in. diameter. The appearance of the completed prototype can be seen from Plate 39, where the head has been fitted just below the leading edge of the guard on the left. This head was provided with rollers so that it would move easily over the work, and it was also provided with a Bowden cable so that the operator could lift it away from the works completely, if this should prove to be necessary in particularly awkward corners.

3. Once again the development work was based on careful observations and the results obtained can be seen from Plates 40 and 41 which were taken from the 35 mm. cinematograph film negative on which the system was designed. Plate 40 shows the machine in use on grey iron without exhaust ventilation. When this photograph was taken the extractor head had been lifted so that the sparks and dust were moving along their natural path in still air. Plate 41 was taken from the same position when the machine was still grinding grey iron, but the new exhaust system is now in use. It will be seen that the extractor head is controlling the dust and most of the sparks as well. This photograph was taken when the exhaust system was operating with a vacuum of just under 4 in. of mercury, but this is rather low, and the system should be run at 5 in. of mercury. The visual evidence obtained from the film itself was confirmed by dust counts done on samples taken by an Owens Jet Counter, a Konimeter and a Thermal Precipitator. The samples were not incinerated, so that the efficiency of the dust control system was estimated on the total dust cloud produced, and all the samples were counted down to the limit of visibility under light field illumination. The machines were run singly in laboratory conditions, so that no estimate could be made of the possible build-up in dust concentration that might result from the use of a large number of machines over a long period. The counts[20] showed no increase in the dust concentration at the breathing level of the operator, whether he was grinding or not, and this evidence, taken in conjunction with the observations, indicates a high level of dust control.

Appendix XVI

LOW VOLUME HIGH VELOCITY DUST CONTROL FOR A PNEUMATIC CHISEL

1. Pneumatic chisels have been commonly used in the past without any kind of dust control, although if the work is small enough to be dressed on a bench, the bench itself may be fitted with local exhaust ventilation[11]. Recent development work, however, has resulted in an original approach to the problem which has provided local exhaust ventilation for the portable tools themselves.

2. The research work was done by two members of an industrial firm, Mr. A. T. Holman and Mr. E. B. James, together with a member of our Committee, Mr. W. B. Lawrie, and it resulted in the first integral local exhaust ventilating system to be fitted to a pneumatic chisel[16]. It was clear from the beginning that the system would have to form an integral part of the tool and that it would have to be light and neat in construction, in order to preserve the flexibility of operation which is a first essential of pneumatic chisels. It had already been shown that the fine dust from a pneumatic chisel flows up the chisel shank and follows the line of the operator's arm to rise to his face[11]. This effect can be seen from Plate 1, which is, in fact, a reproduction of the original photograph from which the effect was discovered. Early experimental work in mining practice had shown that dust could be controlled in the process of rock drilling by extracting it through a hollow drill steel[15], and so the investigators decided to apply a similar principle to a pneumatic chisel.

3. In the early stages of the work, an ordinary pneumatic chisel was used and a ventilating duct was placed by hand above the operator's glove so that it would control the dust as it rose from the chisel point. The necessary vacuum was induced by a compressed air ejector, which was designed to give a static vacuum of 18–20 in. of mercury, and a running vacuum of 10 in. of mercury. This ejector induced 3.2 cu. ft. of free air per minute, and the ventilating air was extracted through a $\frac{5}{8}$-in. diameter flexible hose at a calculated velocity of the order of 12,000 ft. per minute. The dust control that was achieved can be seen from Plate 42, which has been reproduced from the original 35 mm. cinematograph film negative on which all the work was based. A good standard of dust control was achieved by this method, but the research workers discarded it because the duct only controlled the dust which left the front face of the chisel, because its efficiency would clearly vary with the precise position in which it was held, and because it could not be used on long chisels.

4. Experimental hollow chisels were then constructed in which the centre line of the duct coincided with the centre line of the chisel and a pneumatic hammer was modified to take a central duct through which the ventilating air could be extracted. Plates 43 and 44 show the results obtained with these hollow chisels. Both these photographs were taken from the original film which was used for the development work, and Plate 43 shows conditions before starting work. Plate 44 shows the dust control that was

achieved with a vacuum head of 10 in. of mercury. Large particles can be seen leaving the chisel point, but the fine dust of respirable size is under control both at the front and at the back of the chisel.

5. A series of dust samples taken in laboratory conditions with an Owens Jet Counter, a Konimeter and a Thermal Precipitator confirmed these observations. Only one chisel was in use during the tests, and the time for which it was used did not allow of any estimate of the accumulated amount of dust which might build up at the end of a day's work in a full shop using a large number of chisels. On the other hand, both the observation technique and the dust counts indicated a high level of dust control.

6. The laboratory work at this stage led the workers to the following conclusions:

(1) It has been confirmed that the fine dust tends to rise from the point of a pneumatic chisel.

(2) Local exhaust ventilation has been applied to a pneumatic chisel.

(3) A low volume high velocity system of local exhaust ventilation has been developed and it uses on each chisel about 4 cu. ft. of free air per minute at a vacuum of 10 in. of mercury.

(4) The exhaust can be applied through a separate duct fitted down the side of a conventional chisel.

(5) The exhaust can be applied through a hollow chisel.

(6) The extracted air and the dust may he conveyed from the chisel through a central duct fitted in the pneumatic hammer itself.

(7) The exhaust air can be provided by a compressed air ejector or a rotary exhauster.

7. When the original research and development project had been completed, the prohlem of engineering practicability arose and this was considered hy Mr. A. T. Holman and Mr. F. F. L. Morgan from the industrial organisation that had been responsible for the original work, and Mr. W. B. Lawrie of our Committee. A close examination of the earlier work led the investigators to the following conclusions at this stage[20]:

(1) The efficiency of dust control must be maintained especially in the respirable size range.

(2) It would be a considerahle step forward if larger quantities of much coarser dust could be controlled when stripping heavy castings.

(3) It would also be necessary to apply the system to long chisels.

(4) The vacuum should be reduced if possible.

(5) The simplest method of application would obviously be the best.

(6) It was desirable to apply the system in such a way that it could be fitted to existing equipment without major alteration to that equipment.

8. The chisel has now been fitted with a rubber sleeve and ventilating ducts have been incorporated in the rubber in such a fashion that there is one pair of ducts above and one pair below the cutting edge of the chisel. This type of sleeve can be fitted on to any chisel and as the chisel is ground hack the rubber sleeve can be cut away so that its end is kept within about one inch of the cutting edge of the chisel. The dust is extracted through a ⅝-in. diameter plastic hose and a vacuum of 5 in. of mercury is sufficient when the system will extract ahout 6.5 cu. ft. of free air per minute[20]. Plate 45 shows the arrangement.

9. The system was developed by means of the illumination technique and Plates 46 and 47 are reproduced from the original 35 mm. cinematograph film negative. Plate 46 was taken when the chisel was in use to cut flash from a grey iron casting which had been shot blasted. No exhaust ventilation was applied and the dust cloud can be seen as it leaves the point of the chisel. Plate 47 shows the chisel operating in similar conditions,

but the new exhaust system was in use when this photograph was taken and the fine dust can be seen as it moves into the ports both above and below the chisel points in the end of the rubber sleeve. These observations were confirmed by dust counts which indicated a high level of dust control within the respirable size range in the laboratory conditions that were imposed[20].

10. When the pneumatic chisel is used to strip heavy castings, much larger quantities of dust are produced and so a rubber conical extension duct was added to the sleeve to meet these conditions. Plate 48 shows the pneumatic chisel with this extension duct fitted over the sleeve. The high velocity air stream still extracts fine dust generated at the chisel point, but it also serves as a secondary forcing jet to induce a lower velocity air stream round the edge of the cone. This secondary induced stream collects larger quantities of heavier dust which would otherwise escape from the system.

11. Once again the system was examined by means of the illumination technique and Plates 49 and 50 are reproduced from the original film negative[20]. Plate 49 shows the conditions when stripping a heavy steel casting without exhaust ventilation. Plate 50 is a corresponding photograph taken with the ventilating system in use and the extension duct fitted over the chisel sleeve. Heavy particles and chips can be seen flying from the chisel point, but the main dust cloud within the respirable size range appears to be under control.

Appendix XVII

THE WET DE-CORING BAR

1. A member of the staff of the British Cast Iron Research Association, Mr. W. H. White, has designed a bar for wet de-coring[21]. An ordinary bar has been fitted with a ring which carries four jets from which a fine spray of water can be projected round the point of the bar (*see* Plate 51). When the bar is in use, the water spray reaches the core before the point of the bar strikes it, so that the core sand is wetted before being dislodged. This is, therefore, an attempt to eliminate dust at source and not a dust control method, because the moistened sand will be dust free, even when it is knocked out of the casting by the bar.

2. The device was examined by means of the illumination technique, and proved eminently successful on the cores on which it was used[21]. Plate 52 shows conditions before commencing work, and no dust is visible in this photograph. Plate 53 shows the wet bar in use, while Plate 54 shows conditions when the work has been finished. It will be seen that the operation of de-coring with the new bar produces no visible dust in the optical conditions imposed[21], and that the atmosphere was just as free of airborne dust at the end as it was at the start. Plate 55 shows conditions two minutes after finishing work with an ordinary bar when the operation had been done dry. The airborne dust cloud which had been raised is still clearly visible in this photograph.

3. A short series of dust counts was also taken during the experimental work on the process[21]. The Owens Jet Counter and the Thermal Precipitator were used, and the samples, which were taken at the breathing level, were not incinerated. The results confirmed the observations made by the illumination technique.

The Owens Jet samples were estimated[5, 6] and gave a general atmosphere dust concentration of about 1,000 particles per cu. cm. before starting work. This remained constant during the wet de-coring, but rose to 3,600 particles per cu. cm. after dry de-coring. This sample was taken two minutes after dry de-coring had ceased, so that the heavy dust would have had time to fall out of the atmosphere.

The Thermal Precipitator samples were counted under light field illumination to the limit of visibility. This instrument showed a dust concentration of 869 particles per cu. cm. before starting work, with a concentration of 924 particles per cu. cm. after wet de-coring. Dry de-coring, by the old method gave a corresponding dust concentration of 6,980 particles per cu. cm. at the end of the process.

The de-coring bar is now in use in a dressing shop. The preliminary experimental work, however, resulted in the following conclusions.

(1) A fine water spray projected beyond the point of a de-coring bar proved sufficient, in the cases investigated, to wet the sand of the core before it was struck by the bar. In consequence, no dust was raised during the de-coring operation.

(2) The device would not use more than 20 gallons of water per hour with the four jets operating continuously. The water is only needed intermittently, and it has been found, in practice, that the maximum quantity required does not exceed 10 gallons per hour.

Appendix XVIII

NON-FERROUS FOUNDRY ACCIDENTS

Group No.		1953	1954	1955
1	Power-Driven Machinery (except Hoisting Appliances)	68	147 (1)	103
2	Hoisting Appliances	44	126	29
3	Falls of Persons	64	87	67
4	Burns	229	202	248
5	Eye Injuries	108	96	104
6	Hand Tools	59	79	76
7	Handling Material	248	243	281
8	Falling Articles	204 (1)	214 (1)	227
9	Stepping On; Striking Against . .	64	71	70
10	Electrical	2	1	2
11	Transport	24	30	20
12	Miscellaneous	10	81	8
		1,124 (1)	1,377 (2)	1,335

Appendix XIX

REFRACTORY CONCRETE FOR FOUNDRY FLOORS

1. Many foundrymen object to concrete floors because they anticipate danger from the splashes of molten metal which may result if it is spilt on to the floor. Prepared floors need not necessarily be concreted but if this type of floor is chosen the danger due to explosions of molten metal from the floor can be avoided by the use of refractory concrete. This material, which is a true refractory, is called concrete merely because it consists of an aggregate (crushed firebrick) and an aluminous hydraulic cement (Ciment Fondu). It offers the advantages of concrete hardness and easy laying, but bears no other similarity to ordinary concrete.

2. Refractory concrete is used in the construction of furnaces when the recommended maximum temperature is of the order of 1,350° C., but when it is used for a floor, refractory concrete will withstand metals at much higher temperatures than this because of the rapid cooling of the metal on the surface of the floors. In a recent test, a quantity of molten steel was poured on to a refractory concrete slab, which emerged from the test without cracking or spalling and showed no other defect which would have caused it to become unserviceable if it had been part of a floor.

3. The slab, which was not reinforced, was 2 ft. 9 in. square and 6 in. thick and was made from the following mix:

One part Ciment Fondu
Two parts crushed firebrick aggregate $\frac{1}{8}$ in. down
Three parts crushed firehrick $\frac{3}{4}$ in. to $\frac{1}{8}$ in.

The concrete was mixed and compacted in the usual manner and the top surface was then brought to a smooth state by trowelling. The slab was allowed to dry in the air and when it was one week old it was placed on the floor of a steel casting pit with the trowelled face uppermost. A ladle of molten steel containing about 50 tons at a temperature of about 1,600° C. was hung from a crane in such a position that the nozzle, which was 1 in. in diameter, was about 7 ft. above the top of the refractory concrete slab. The stopper was then opened wide and the steel was allowed to pour freely on to the refractory concrete. Plate 56 shows the slab under the stream of molten steel. As soon as the slah was cool enough it was lifted for examination and Plate 57 shows the condition of the concrete with some of the steel which had solidified on it. This steel was removed quite easily as it did not adhere to the refractory concrete and the condition of the slab after the steel had been removed can be seen in Plate 58. The part of the slab which had taken the main impact of the metal stream was completely undamaged. Nearer the edges of the slab, however, where some indirect splashes of steel had struck the concrete, there were several small blemishes, each of which was about three-quarters of an inch in diameter with a maximum depth of about one-sixteenth of an inch.

The test indicated that refractory concrete does not spall or split, even under these severe conditions, so that there is no danger of accidents from explosions. The solidified metal can be removed from the floor quite easily and is fit for re-melting as there is relatively no pick-up from the floor itself.

4. The aggregate is comparatively soft, but if the refractory floor is properly cured by keeping it wet for the first 24 hours it should give a resistance to wear comparable with the average Portland cement/gravel concrete floor. Refractory concrete floors and gangways should have a minimum thickness of four inches, when they will be strong enough to stand severe conditions of service even if they are laid on a soft base such as a foundry sand. The following mixture is suitable for all situations in foundries where refractoriness and resistance to wear are needed and is particularly recommended where furnace breakouts or excessive spillage of molten metal may be anticipated:

Fine firebrick aggregate ($\frac{1}{8}$ in. down) 2 cu. ft.
Coarse firebrick aggregate ($\frac{3}{8}$ in. to $\frac{1}{8}$ in.) 2 cu. ft.
Ciment Fondu 1 cu. ft.

In places where the danger from molten metal might not be so great but where increased resistance to wear would be useful the fine firebrick aggregate in the above mixture can be replaced by ordinary silica sand of a similar grading. This will give the floor increased durability without seriously affecting its refractoriness.

5. Refractory concrete is mixed and placed in very much the same way as ordinary concrete. Refractory aggregates are particularly porous, however, and so require pre-soaking if the best results are to be achieved and they should be placed in a mixer with a liberal quantity of water, when the mixer should be rotated for a sufficiently long time, usually about five minutes, before excess water (if any remains) is drained off and the Ciment Fondu added. More water can then be added if necessary to bring the mix to the correct consistency. The best wearing surface will be obtained if the concrete is not over trowelled. Trowelling should be confined to an initial screeding with a final trowelling when the concrete has started to set and when fairly heavy pressure is needed to bring any water to the surface. The floor should then be kept moist for 24 hours and this is most important. This watering or curing can be carried out by means of a sprinkler or by laying wet sacks over the entire area. Curing should be started immediately the floor surface is hard enough to remain undamaged and during this period the floor should be protected if possible from radiant heat. One way of doing this, of course, is to keep the floor thoroughly wet. The floor can then be put into service after 24 hours, although another day or two should be allowed for the surface to dry up thoroughly, particularly if there is any immediate danger of molten metal splashing on to the floor. The floor can be patched by cutting out the damaged surface leaving slight undercut edges, provided that the surfaces at which the new concrete and the old concrete are in contact are brushed with a slurry of neat Ciment Fondu and water just prior to placing the patching concrete.

6. Temporary or movable gangways can be constructed by using pre-cast refractory concrete slabs. These can be made in wooden moulds and should be at least three to four inches thick, when they will make a good gangway if they are evenly laid.

7. Acknowledgements are due to the Directors of Lafarge Aluminous Cement Co., Ltd., for much of the information contained in this Appendix.

APPENDIX XX

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Plate 1. Fine dust cloud rising from pneumatic chisel. No exhaust ventilation in use.

Photograph by courtesy of the Institute of British Foundrymen

Plate 2. Dust stream flowing from hood of stand grinder. Conventional local exhaust ventilation fitted and operating.

Photograph by courtesy of the Institute of British Foundrymen

Plate 3. Dust cloud generated by portable abrasive wheel. No local exhaust ventilation in use.

Photograph by courtesy of the Institute of British Foundrymen

Plate 4. Fume produced by the application of flux to molten magnesium—without exhaust.

Photograph by courtesy of the British Cast Iron Research Association

Plate 5. Fume control by circular duct. Slight leakage at left as experimental ring did not quite fit the crucible.

Photograph by courtesy of the British Cast Iron Research Association

Plate 6. Fume from magnesium casting immediately after pouring—no exhaust.

Photograph by courtesy of the British Cast Iron Research Association

Plate 7. Fume from magnesium casting immediately after pouring—with exhaust. Note fume from vent also flowing into exhaust ring.

Photograph by courtesy of the British Cast Iron Research Association

Plate 8. Arrangement of knock-out.

Plate 9. Knocking-out without exhaust.

Plate 10. Knocking-out with exhaust.

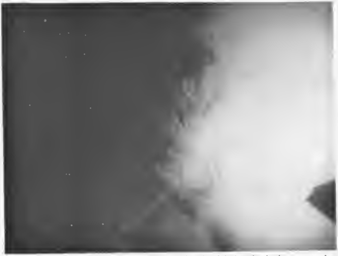


Plate 11. Knocking-out without exhaust. The cloud is just beginning to envelop the operator (Cp. Plates 9 and 10).

Plate 12. Knocking-out with exhaust showing the control achieved as the top box is lifted.

Plate 13. Knocking-out with exhaust showing normal control.

Plate 14. Primary dust stream flowing from hood with conventional local exhaust system fitted and operating. 14-in. diameter wheel.

Photograph by courtesy of the Institute of British Foundrymen

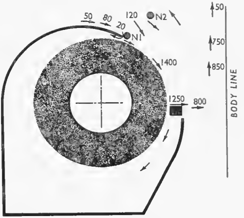


Plate 15. Air movement due to the rotation of the 14-in. diameter wheel. Exhaust not operating. Figures indicate air velocities in feet per minute.

Illustration by courtesy of the Institute of British Foundrymen

Plate 16. Grinding grey iron without local exhaust ventilation.

Photograph by courtesy of the Institute of British Foundrymen

Plate 17. The external system with the exhaust fully operative. Dust control when grinding grey iron.

Photograph by courtesy of the Institute of British Foundrymen

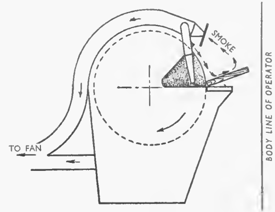


Plate 18 (*a*). Diagrammatic sketch of the combined exhaust system.
(*b*). Grinding wood, showing good smoke control.

Photograph by courtesy of the Institute of British Foundrymen

Plate 19. Combined system with worn 16-in. diameter wheel in use. Good dust control in spite of large gap over wheel top.

Photograph by courtesy of the Institute of British Foundrymen

Plate 20. Wheel hood with front plate removed.

Photograph by courtesy of the Institution of Mechanical Engineers

Plate 21. Dust control when grinding grey iron with exhaust system operating at five inches of mercury. Heavy particles falling. Right-hand edge of dust cloud under control by the induced air.

Photograph by courtesy of the Institution of Mechanical Engineers

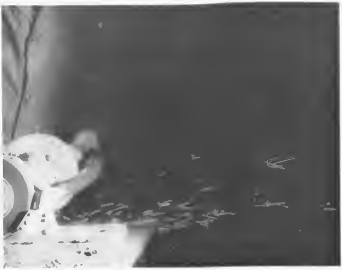


Plate 22. Grinding grey iron with extractor head fitted and operating (Cp. Plate 23).

Photograph by courtesy of the Foundry Trade Journal

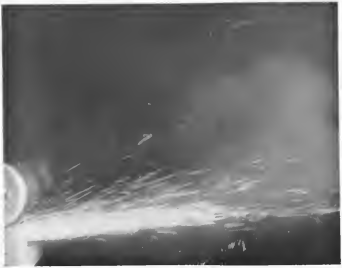


Plate 23. Grinding grey iron without exhaust ventilation.

Photograph by courtesy of the Foundry Trade Journal

Plate 24. Eight-inch diameter bench grinder.

Photograph by courtesy of the Foundry Trade Journal

Plate 25. Bench grinder without local exhaust ventilation.

Photograph by courtesy of the British Cast Iron Research Association

Plate 26. Bench grinder with new exhaust system fitted and operating.

Photograph by courtesy of the British Cast Iron Research Association

Plate 27. The portable surface grinder.

Photograph by courtesy of the British Cast Iron Research Association

Plate 32. Ventilation system fitted to portable surface grinder. Part of ring cut away to facilitate the use of the wheel.

Photograph by courtesy of the Foundry Trade Journa

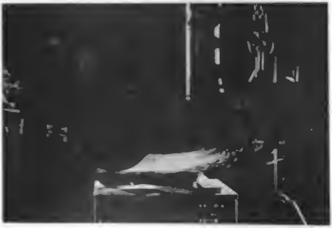
Plate 33. Grinding grey iron castings. Ventilating system not in use.

Photograph by courtesy of the Foundry Trade Journal

Plate 34. Grinding grey iron with the ventilating system operating (Cp. Plate 33).

Photograph by courtesy of the Foundry Trade Journal

(*a*)



(*b*)

Plate 35 (*a*). Dust clouds generated when grinding pig iron with a conventional machine.

(*b*). Dust control obtained when grinding the same pig iron with a machine incorporating the B.S.C.R.A. integral exhaust system.

Photographs by courtesy of the British Steel Castings Research Association

Plate 36. Grinding grey iron without exhaust.

Photograph by courtesy of the British Cast Iron Research Association

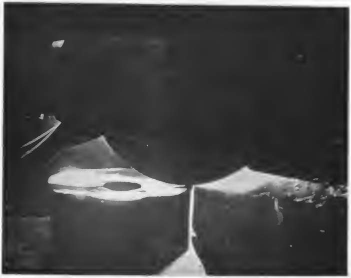


Plate 37. Grinding grey iron. Dust control with new system operating. Leading edge of guard over floor.

Photograph by courtesy of the British Cast Iron Research Association

Plate 38. Grinding grey iron. Dust control with new system operating. Trailing edge of guard over floor.

Photograph by courtesy of the British Cast Iron Research Association

Plate 39. Extractor head fitted to transverse swing frame grinder.

Photograph by courtesy of the Foundry Trade Journal

Plate 40. Grinding grey iron without exhaust ventilation.

Photograph by courtesy of the Foundry Trade Journal

Plate 41. Grinding grey iron with extractor head fitted and operating (Cp. Plate 40).

Photograph by courtesy of the Foundry Trade Journal

Plate 42. Dust control by external duct held over chisel point.

Photograph by courtesy of the Institution of Mechanical Engineers

Plate 43. Hollow chisel before starting work.

Photograph by courtesy of the Institution of Mechanical Engineers

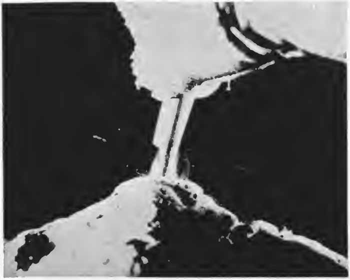


Plate 44. Hollow chisel working on a projection. Exhaust system at a vacuum of ten inches of mercury.

Photograph by courtesy of the Institution of Mechanical Engineers

Plate 45. Pneumatic chisel fitted with rubber sleeve.

Photograph by courtesy of the Foundry Trade Journal

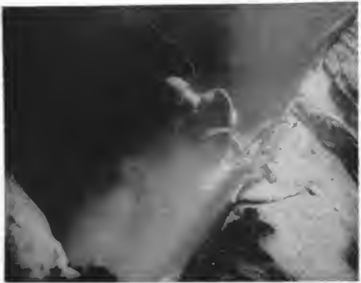


Plate 49. Stripping heavy steel casting with pneumatic chisel. No exhaust ventilation in use.

Photograph by courtesy of the Foundry Trade Journal

Plate 50. Stripping heavy steel casting with pneumatic chisel fitted with sleeve and conical extension duct. Exhaust ventilation system working. Heavy particles flying from chisel. (Cp. Plate 49.)

Photograph by courtesy of the Foundry Trade Journal

Plate 51. De-coring bar fitted with spray nozzles.

Photograph by courtesy of the British Cast Iron Research Association

Plate 52. Conditions before starting work. No visible dust in atmosphere.

Photograph by courtesy of the British Cast Iron Research Association

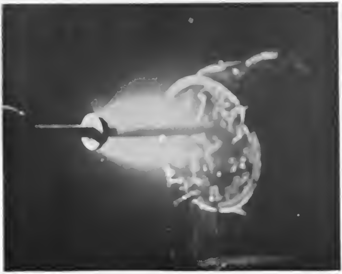


Plate 53. Conditions when de-coring wet. No visible dust in atmosphere.

Photograph by courtesy of the British Cast Iron Research Association

Plate 54. Conditions after finishing wet de-coring. No visible dust in atmosphere.

Photograph by courtesy of the British Cast Iron Research Association

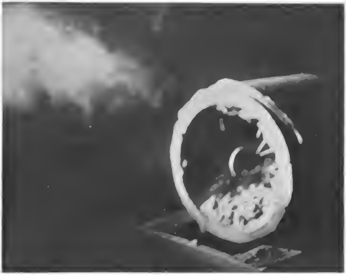


Plate 55. Conditions two minutes after finishing dry de-coring. Note atmospheric dust cloud.

Photograph by courtesy of the British Cast Iron Research Association

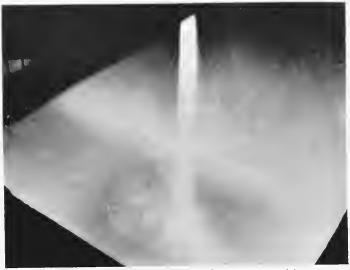


Plate 56. Molten steel pouring on to refractory concrete slab.

Plate 57. Refractory concrete slab after test with some solidified steel adhering.

Plate 58. Condition of slab after adhering steel had been removed, note undamaged centre which withstood the main shock.

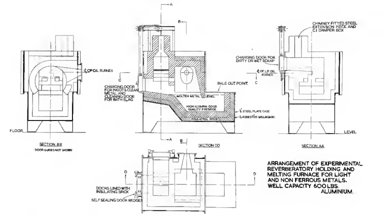
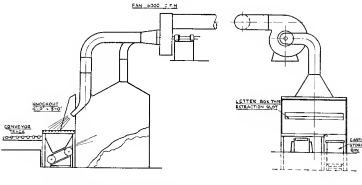


Figure 2

Illustration by courtesy of Metal Industry



FUME & DUST EXTRACTION FROM FOUNDRY KNOCKOUT

Fig 5 General arrangement of the knock-out.